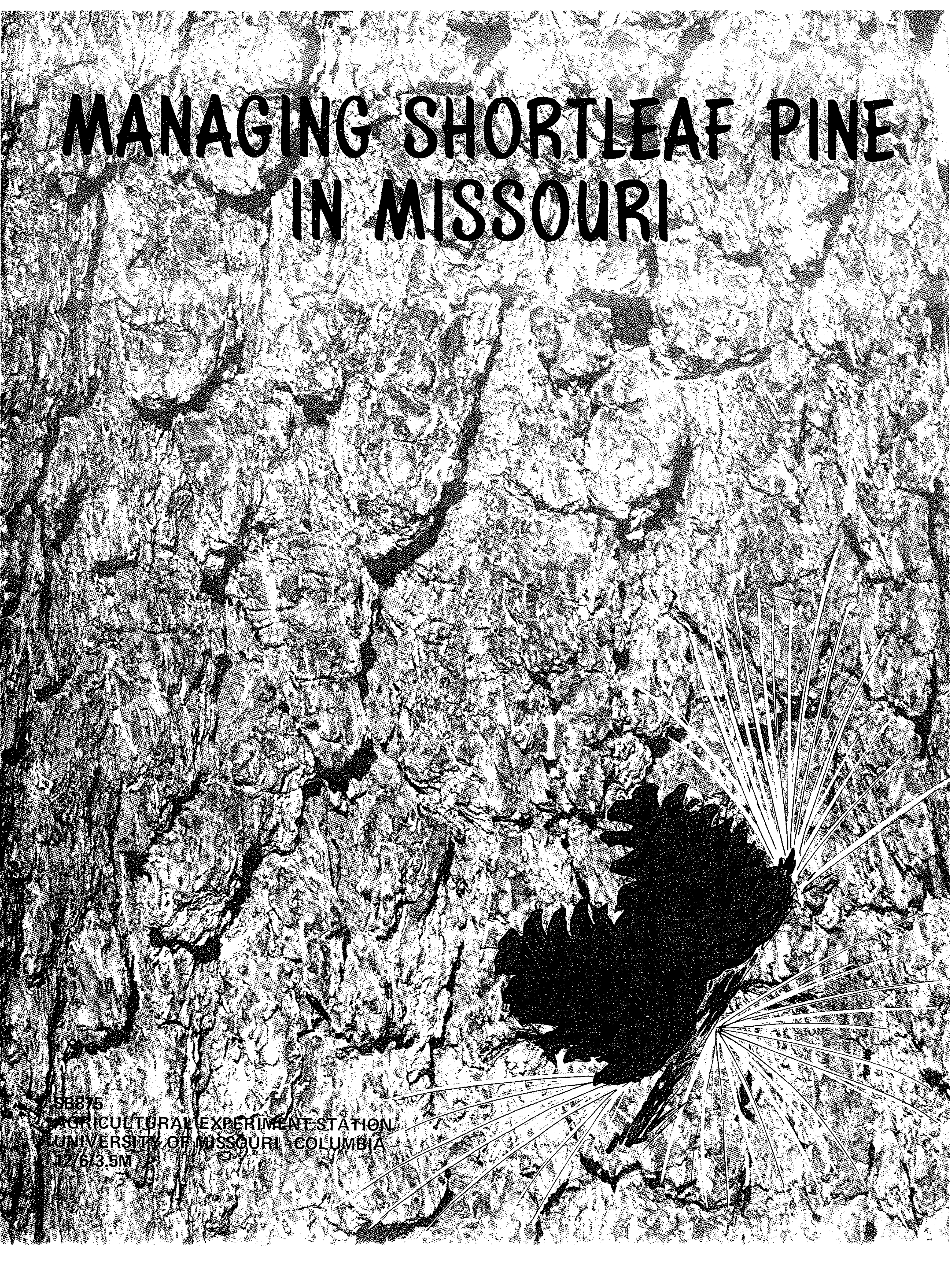
MANAGING SHORTLEAF PINE IN MISSOURI



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Managing Shortleaf Pine

in Missouri

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ABSTRACT

Management of shortleaf pine can be profitable in Missouri where pine and oak-pine stands occur in a six-million-acre area. Pines of post-size or larger are marketable, often at twice the price of oaks. Where the black oak site index ranges from 45 to 65, managed pine stands will produce 40 percent more volume than oaks.

On average sites, annual height growth of pines with adequate crowns will be 1.5 to 2 feet to age 25, 1.0 foot from age 25 to 40, 0.8 foot from age 41 to 60, and 0.5 foot thereafter. Diameters of post-size and larger trees increase about two inches with every 10-foot increase in total height, reaching 17 to 19 inches by age 70. Fire and insect losses are low in the pine type. Root rot (*Fomes annosus)* is a potential threat only on old-field sites.

Pine stands may be established by natural seeding, planting, or direct seeding, but excess hardwoods must be controlled and prescribed burning may be necessary to prepare the seedbed. Manage pine and oak-pine types as even-aged stands. Thin at 8- to 10-year intervals beginning about age 25. Economic rotation age is 60 to 70 years on most sites. Profitability of pine management is largely determined by site quality and cost of regeneration.

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Foreword

This report presents a summary of what is known about site requirements, regeneration, protection, growth rates, and yields of shortleaf pine stands in Missouri. Results of research and the knowledge and experience of state, federal, and private foresters are combined to provide workable guidelines for the management of this valuable species. How various combinations of rotation length, site quality, costs of treatment, and value of products affect the profitability of managing pine in Missouri is analyzed.

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Introduction

Shortleaf pine (*Pinus echinata* Mill.) has the widest range of the four principal southern pines and is the only pine native to Missouri (U.S. Forest Serv., 1965b).[2] Foresters prefer pine to most associated hardwoods because of its higher value, faster growth rate, and relative ease of establishment. On sites capable of growing either pine or oaks, managed pine stands will produce at least 40 percent more merchantable volume per acre than oak stands. Best growth occurs within its natural range, but shortleaf pine has been planted successfully in many other parts of

2. Authors and dates in parentheses refer to Literature Citations.

Missouri. As a result of more intensive management to favor pine, the percentage of pine in oak-pine stands and the acreage of stands where pine is the major component are increasing.

In the virgin forests, oaks were more abundant than pine, and essentially pure stands of pine were limited to small scattered areas. Record (1910) observed in 1906 that the better pine stands contained volumes "ranging from 1,200 to 12,000 board feet per acre with a probable average of about 2,500 board feet... One acre in Carter County was known to contain 115 merchantable trees (13 inches +) with a total volume of 25,000 feet." Pine was a highly desired timber species when logging reached its peak in Missouri between 1900 and 1920.

The Missouri Ozark area is close to large population centers that provide a continuing market for pine lumber. Posts and poles are readily salable as treated products. When the supply of pine cordwood becomes adequate, there seems little doubt that pine will be used with the abundant hardwoods by the pulp and paper industry.

Even with present markets, however, shortleaf pine is well suited to intensive management because trees of nearly any size can be sold. Beginning at about age 25, pine stands may be thinned for posts; and pine sawlogs consistently sell for more than oak logs of the same size. Pine and oaks can be grown together, but on suitable sites the timberland owner will usually make more money managing to favor pine.

This publication presents what is known about the management of shortleaf pine in Missouri. Basic information includes the silvical characteristics of the species, methods of regenerating and protecting stands, and available data on growth, yields, and costs and returns for managed plantations and natural stands. Oak-pine stands are not discussed since no data are available on their growth and yield. Also, because no pine stands have been managed longer than about 30 years, data for total yields over a full rotation are incomplete. Plantations are relatively young and none have been thinned more than three times. In spite of such deficiencies, enough is known about pine to provide management guidelines and predict the profitability of growing pine.

Silvics of Shortleaf Pine in Missouri

In Missouri, shortleaf pine is growing in the northwest extension of its wide range. Although shortleaf is the least exacting of the southern pines with regard to temperature and moisture requirements, its natural range and productivity are limited by climate and other factors such as the nature of the soil, topographic position, competition from other species, and the possible adverse effects of animals, disease, and insects.

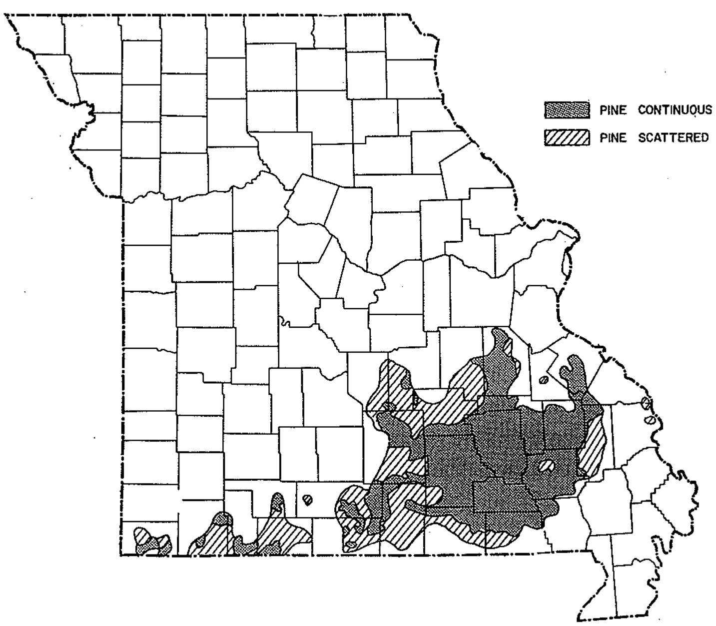

Figure 1. Natural range of shortleaf pine in Missouri.

Range and Distribution

The natural range of shortleaf pine in Missouri lies entirely within the Ozark region (Fig. 1). Pine is most abundant where the topography is rolling to steep and soils are classed as stony loams. Pine-bearing lands are nearly continuous in an area of about 4.2 million acres, but this includes small pine-free areas. Scattered individual trees and small stands that may be several miles apart occur over an additional area of about 2.4 million acres (Liming, 1946b).

Even within its natural range, pine does not occur on all sites, of course, and it is absent on some areas that once supported pine stands as shown by old pine stumps and knots. Cutting, repeated burning, land clearing, and the natural succession toward shade-tolerant hardwoods have combined to eliminate pine in places. But pine still occurs in essentially the same general areas where it existed a century ago. With improved fire protection, planting and seeding, and management to favor pine in oak-pine stands, shortleaf pine is becoming more abundant. The range is being extended by planting in other parts of Missouri.

A report on Missouri's forests (Gansner, 1965a) showed that the area occupied by the pine type increased 46 percent between 1947 and 1959, and sawtimber stand acreage tripled. Stands in which shortleaf pine was the major component occupied about 330,000 acres, and oak-pine stands were found on an additional 639,000 acres.

Although shortleaf pine may occur in pure stands in Missouri, it nearly always is found growing in mixture with other hardwoods. White oak (*Quercus alba* L.), black oak (*Q. velutina* Lam.), and scarlet oak (*Q. coccinea* Meunchh.) are the most important associates on the better sites with some bitternut hickory (*Carya cordiformis* [Wangenh.] K. Koch) and blackgum (Nyssa sylvatica Marsh.). On the poorer sites, blackjack oak (*Q. marilandica* Muenchh.) and post oak (*Q. stellata* Wangenh.) often predominate.

Habitat Conditions

Climate

Minor differences in local climate limit the natural distribution and regeneration of pine in Missouri. Over most of the species' range, annual precipitation is at least 40 inches, but pine distribution apparently is related to the amount of winter precipitation. Fletcher and McDermott (1957) reported that average winter precipitation is less than 17 inches north of the pine range in Missouri. Although pine can be grown north of this zone, good survival and growth depend on an adequate supply of moisture during the wintertime. This supply may be influenced by soil characteristics.

In the Ozarks, the average annual temperature is about 58° and that of summer is 74°. High summer temperatures and erratic rainfall are responsible for high evapotranspiration losses and limited supplies of available moisture.

Soils and Topography

In the Ozark Region, nearly all upland soils are residual from cherty limestones and sandstones (Krusekopf, 1963). Weathering and erosion have left varying amounts of chert: In about half the soils chert makes up 30 percent or more of the volume. A thin layer of loess material deposited during glacial periods has been eroded from all but level ridgetops and flat upland areas where an impermeable fragipan nearly always is present. Because of high chert content or limited depth to a fragipan, most forest soils in the Ozarks can store only two to four inches of water in the upper 3-foot layer (Scrivner *et al.,* 1966).

Ridgetops, upper slopes, and south and west exposures dry out faster than lower slopes and north and east exposures. In general, soils with a high chert content or a fragipan or both are more drouthy than soils containing more silt and clay particles.

On many Ozark forest sites, available soil moisture determines which species prevails. Pine is more drouth resistant than any of the associated hardwood species except post oak and blackjack oak. Because it generally grows faster than the latter species on dry sites, pine may form essentially pure stands where moisture is limited.

Where the moisture supply is less critical, the proportion of pine in unmanaged stands tends to decrease. Although pine grows well on nearly all soils of the Ozark Region, species such as black oak, northern red oak *(Quercus rubra L.)*, and scarlet oak will overtop pine on the better forest sites. In contrast, the shallow glade soils of southwest Missouri are too drouthy even for pine, although high pH also may be a deterrent factor. And on some upland flats now stocked with post oak and blackjack oak, soils are underlain by a dense fragipan layer that keeps them waterlogged in the winter and spring. Pine may persist on poor forest sites but the trees grow slowly.

The deep loess soils along the Missouri and Mississippi Rivers are excellent forest sites that are better suited for production of high-quality hardwood than of pine. North of the Missouri River, most soils are of glacial origin overlain with a loess deposit of various thicknesses; these soils contain more fine silt particles and have heavier subsoils than the rocky residual soils of the Ozarks. Limited internal drainage makes many glacial soils poorly suited for growing pine.

Reproduction and Early Growth

Flowering and Fruiting

In Missouri, staminate strobili usually appear about April 15, and pistillate strobili about 10 days later. Open-grown trees may flower somewhat earlier than trees in forests. Extended rainy periods or cold weather during time of flowering may cause poor crops of seed (Schoenike, 1965). Pine seeds mature at the end of the second growing season.

Shortleaf pines do not produce seed in abundance until they reach a diameter of about eight inches. Many large-crowned trees start bearing viable seed when 20 years old, and some trees produce seed even earlier.

Seedfall and Dissemination

Seedfall generally begins in late October, reaches a peak in mid-November, and is 90-percent completed within two months. Some seeds fall as late as April, but seeds shed during the period of maximum fall usually are larger and more viable than others.

The cones are small—1,400 to 2,500 per bushel—and are difficult to detach from the tree. Each cone yields from 25 to 35 seeds. The small seeds average 48,000 per pound. Good seed crops generally occur at intervals of three to 10 years (U.S. Forest Serv. 1948).

Seed production can be stimulated by heavy thinnings in stands over 30 years old (Phares and Rogers, 1962). Trees with large full crowns produce the most seed. Trees treated with fertilizers high in phosphate or potash may yield twice as many sound seed as untreated trees on Ozark sites (Brinkman, 1962).

Seedling Development

Pine seeds that fall in late November and December germinate the following May. Seedling establishment is best on exposed mineral soil or on the light duff layer remaining after a ground fire. Although light overhead shade is desirable during the first few months, best development of pine seedlings occurs in nearly full sunlight.

Early in the first growing season, open-grown shortleaf pine seedlings form a characteristic J-shaped crook at the ground line (Little and Mergen, 1966). Axillary and other buds that develop in the general vicinity of the crook are capable of sprouting if the upper stem is burned or broken off (Stone and Stone, 1954).

On average sites, trees free to grow reach a height of about 12 feet and a d.b.h. (diameter breast height) of about two inches in seven years. By age 20, trees are about 35 feet tall with an average d.b.h. of five inches.

Reaction to Competition

Although shortleaf pine is classed as intolerant of shade, some trees will persist under a hardwood overstory for many years. Overtopped trees grow slowly, however, and many are damaged by tipmoths or rust.

Pines respond well to release even at a late age. For example, a 1939 underplanting was successfully released in 1955 by aerial spraying of the hardwoods. This area now supports an excellent pine stand that is making good growth (Fig. 2). Other underplantings have been successfully released after 30 years.

Studies show that planted or seeded pine should be released promptly and completely for best growth and survival (Liming and Seizert, 1943; Liming, 1946a; Brinkman and Liming, 1961). Where two-thirds of the overstory was cut, height growth of the planted pines was twice that of unreleased trees in 11 years. And where all the overstory was removed, the pines grew five times as much. Season and method of release generally did not influence survival.

Figure 2. Underplanted shortleaf pine released after 16 years by aerial application of herbicides. Picture was taken six years later. (F-518228)

Growth Rate--Pole Size to Maturity

Height Growth

On average Missouri sites, shortleaf pines may attain heights of 70 to 80 feet at maturity. Rate of height growth varies with age. By the time trees are 30 years old, they will be 45 to 50 feet tall. Annual height increments thereafter are about 1 foot per year to age 40, decreasing to 0.7 foot by age 60 and 0.5 foot or less after that.

Height growth rate also varies with site index, which usually is expressed as the height dominant trees will attain in 50 years. The site index curves in Figure 3 are useful for estimating site quality and predicting the height growth potential, particularly for young stands.

Height growth begins about April 25 and generally is more than 95 percent completed by the end of August. Trees do not grow continuously during this period; rather, height is added in several flushes of growth, each with a whorl of branches at the base. Seedlings and small saplings may make another flush of growth as late as September if heavy rains occur.

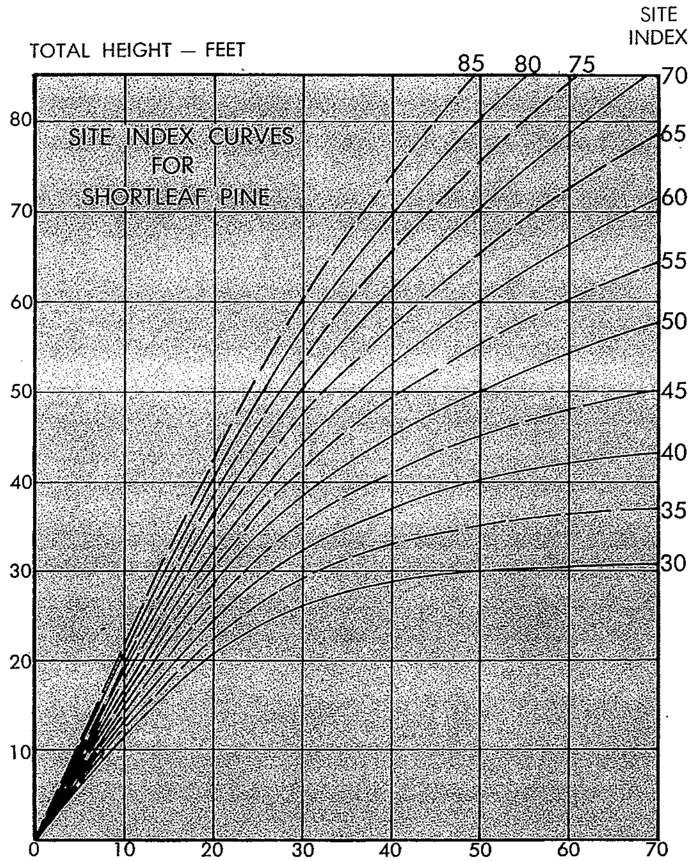

Figure 3. Site index curves for shortleaf pine in Missouri (from Nash 1963).

Diameter Growth

Rate of diameter growth depends more on crown size and the growing space available than on site index. In general, good diameter growth requires a crown length at least 35 percent of tree height, with the crown free to develop on two or three sides.

Dominant and codominant trees on average sites will be about nine inches d.b.h. by age 40 and 18 to 20 inches d.b.h. by age 80. Periodic thinnings can shorten the time required to produce large, high-quality trees in the main stand.

Natural Regeneration

Adequate natural regeneration of pine will result only when three requirements are met: (1) a good seed supply; (2) a suitable seedbed; and (3) minimum competition from hardwoods (Liming, 1945). Similar limitations apply to successful direct seeding. The chief difference is that the seed is sown instead of coming from seed trees.

Seed Trees

As a rule, six to eight well-located seed trees per acre will provide enough natural reproduction on suitable seedbeds within five years. Fewer seed trees or a series of poor seed years will increase the time required. Where possible, it is better to leave about 25 seed trees per acre to reduce the seeding period; such trees can be harvested after they have served their purpose.

Shortleaf pine seeds may be carried as far as a quarter of a mile by strong winds, but most seeds fall within 200 to 250 feet of the tree. The prevailing winds during peak seedfall are from the south or west, so seed trees on these sides of the area to be seeded are most effective, particularly when the trees are located on ridges.

Seed trees should be well formed and at least 10 to 12 inches in diameter. Crowns should be well developed and show evidence of having produced seed in the past. Seed from crooked, excessively branched trees or from trees having many *Cronartium* galls may result in a stand of poor-quality trees.

Seedbed Requirements

Although seedbed preparation usually improves seedling establishment, the treatment required varies with

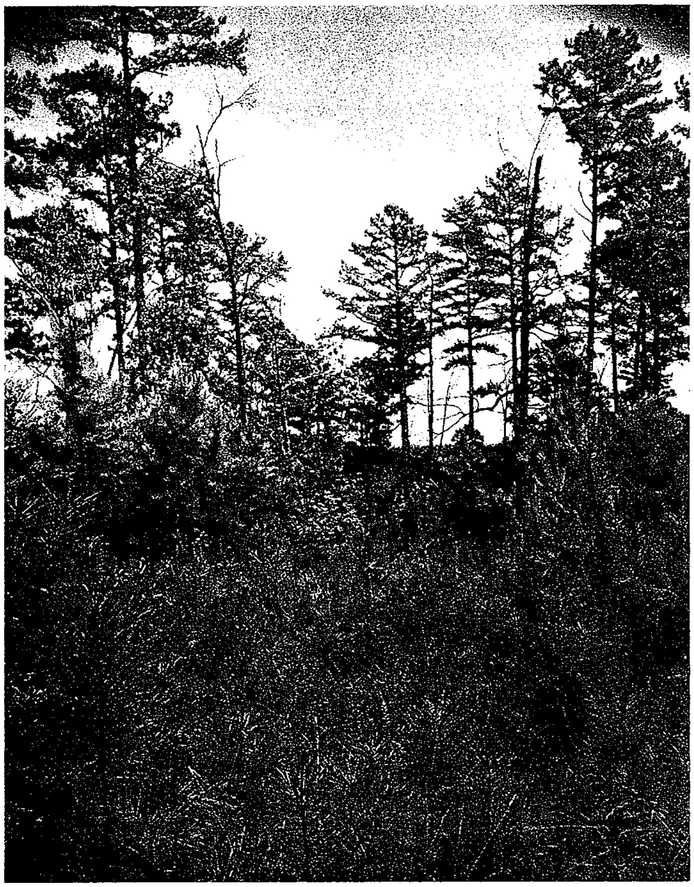

Figure 4. Natural pine reproduction developed on this area after the oaks were harvested and other hardwoods treated with herbicide. (F-518221)

site conditions. In oak-pine stands, abundant pine reproduction may follow the harvest of merchantable hardwoods if cull trees and hardwood sprouts are killed. Disturbance of the litter by logging operations may provide an adequate seedbed (Fig. 4).

Seedling establishment is nearly impossible where dead leaves accumulate in logging slash or brush, or where the leaves form a nearly continuous layer over most of the area (Fig. 5). Completely bare ground is not necessary, however, and a thin duff layer consisting of partially decayed leaves is not an obstacle. Although heavy litter and logging debris can be reduced by bulldozing or disking, the cheapest way is to make a light prescribed burn late in the growing season just before a good pine seed crop falls.

In a Texas study of prescribed burns made in different seasons prior to a good shortleaf pine seed crop, Ferguson (1958) found that significantly more pine seeds germinated if the burn was made the year preceding seedfall. Growing-season burns generally were superior to dormant-season burns in securing a good stand of seedlings.

Burning can be hazardous; fire lines should be prepared in advance and the burn made only when the risk of uncontrollable fire is low. A hot fire is not necessary. The objective is to remove heavy litter and slash from a least two-thirds of the area.

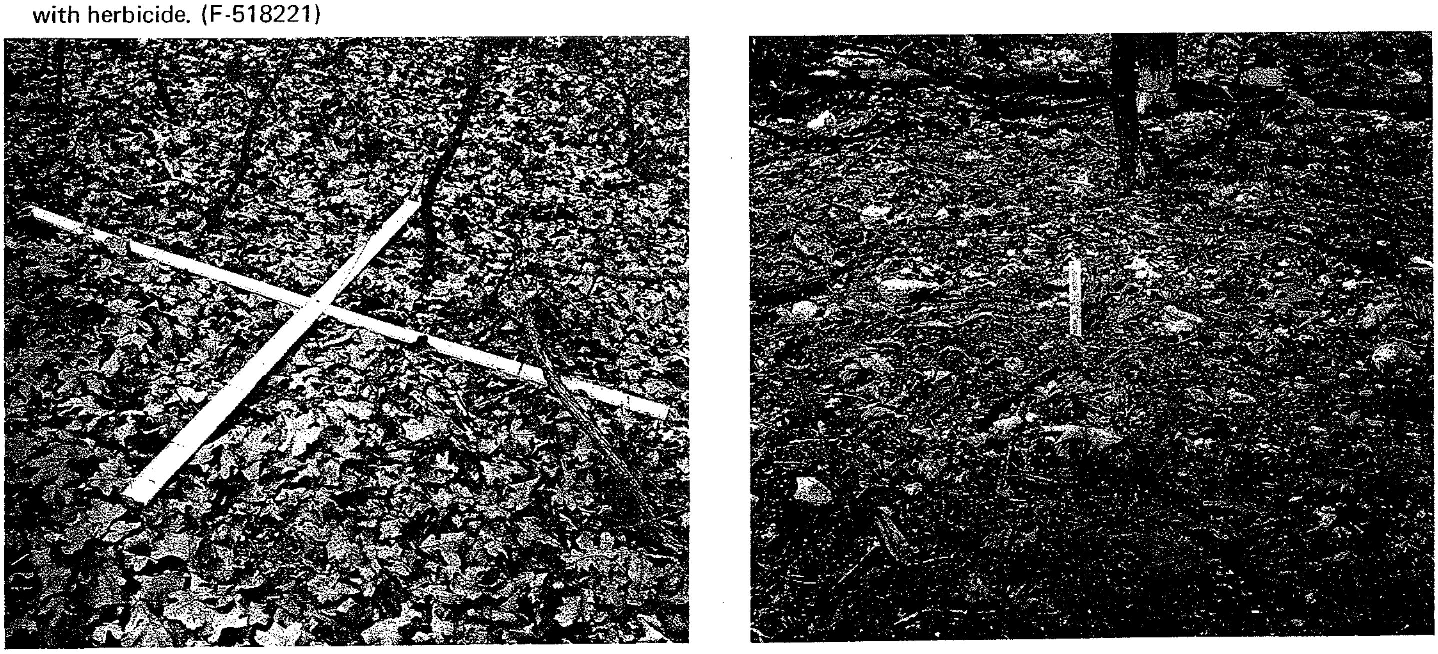

Figure 5. Effects of prescribed burn for site preparation. In left photo this thick layer of leaves will prevent successful natural pine regeneration; (right photo) a light prescribed burn has destroyed most of the leaves but left the duff layer intact. (F-518223, F-518227)

Prescribed burning requires that a fire line be cleared down to mineral soil around the area to be burned. This is frequently done with a tractor and a bulldozer or fire plow. Several men are needed to do the burning and prevent the fire from escaping. Prescribed burning of an 80-acre tract, for example, may require 12 tractor hours and 40 man-hours. Burning has been done in Missouri at a cost of $1 to $3 per acre.[3]

Where burning is not possible, the seedbed can be prepared by light scalping with a bulldozer blade or by disking at a cost of about $10 per acre. As with burning, complete destruction of the litter and slash is not necessary (Sander, 1963). To reduce costs, work around standing trees where possible, pushing over only those small trees that cannot be avoided. This treatment is expensive; unless a good pine seed crop is present on seed trees, the area should be direct-seeded.

Hardwood Control

When preparing pine sites for regeneration, merchantable trees should be harvested and the others killed with herbicides. Standing dead trees provide light shade favorable to germinating pine and need not be cut. Where natural regeneration is planned, pine seed trees should be left.

A dense hardwood understory often is the major obstacle to successful pine regeneration. On pine sites, most understory hardwoods are shade-tolerant species with less potential value than pine for timber production. Hardwoods cast heavy shade, and their established root systems use most of the available soil moisture during the frequent summer drouths when the moisture supply becomes critical for pine seedlings.

For best results, unwanted understory hardwoods should be killed during the late spring or early summer before a good pine seed crop is expected. Delaying application of herbicides to control hardwoods until pine seedlings are established often results in damage to the young pines. At least two-thirds of the regeneration area should be essentially free of understory hardwoods.

Axe-frill and injection methods are commonly used for killing culls and other large unwanted hardwoods. With the frill method, overlapping downward cuts are made on the tree as low as practicable, and the frill is filled with a 2, 4, 5-T ester-diesel oil mixture. Generally, a 1-to-24 mixture is satisfactory when the chemical contains four pounds of acid equivalent per gallon (Brinkman, 1960).

Figure 6. Applying herbicide with a tractor-mounted mist-blower. (F-518229)

Injectors give good results, are somewhat safer to use, and require less labor than the axe-frill system. Solutions of 2, 4, 5-T in oil or 2, 4-D amine in water can be applied with unmetered injectors. However, chemical costs are least when metered injectors are used to apply undiluted 2, 4-D amine. Injections at spacings of an inch or less are best, but good kill results where injections are spaced no more than two inches apart and placed low on the stem. Trees as small as two inches in diameter at the ground line can be treated.

Dense stands of small hardwoods can be killed with a mist-blower using about two pounds (acid equivalent) of 2, 4, 5-T per acre (Fig. 6). Basal sprays of one part 2, 4, 5-T ester (four pounds acid equivalent) to 19 parts of diesel oil also are effective, but cost of material and labor will be higher. Where large areas are treated, most hardwoods can be controlled by aerial application of two pounds of 2, 4, 5-T per acre.

Species, site, and time of application may cause variations in results. In general, foliage applications should be made in the spring after leaves are fully developed, but frill and injector applications with the right chemicals may be made at any convenient time.

Several combinations of chemicals and equipment may be used. Costs vary with the type of equipment employed, acreage covered, number and size of stems treated, chemicals used and their concentration, type of carrier or solvent, crew organization, and rate of pay. The following cost data for large areas include labor, equipment charges, materials, and transportation of labor to

3. When available, cost records are from literature cited. Costs without specific citation were obtained from the Clark and Mark Twain National Forests and the Missouri Department of Conservation; data frequently were averaged or rounded to indicate only their general level. Costs vary with the specific job and records often do not adequately describe what was done. In periods of rising prices, figures soon become out-dated.

the site. On small tracts with steep topography or large numbers of trees to treat, costs may be considerably higher.

METHOD	COST PER ACRE *Typical*	*Range*
Girdling with axe, no chemical	$4.00	
Girdling with axe, chemical used	4.50	4.20—5.20
Tree injector	4.15	2.50—7.50
Portable mist-sprayer	6.25	4.25—9.85
Tractor-mounted mist-blower	6.00	5.40—7.60
Aerial spraying	6.30	4.90—7.75

Although fire is often used to prepare the seedbed, burning does not control young hardwoods. Paulsell (1957) reported that annual or periodic fires killed the tops but not the roots of small trees, and Williamson (1964) found that the number of hardwood stems doubled after a prescribed burn. The vigorous sprouts compete with pine seedlings even more effectively than before.

Young pine stands may require release from competing vegetation so the trees will be free to grow. Although annual weeds often overtop young pines during the first growing season, such weeds seldom reduce survival and growth rate. Where sites were adequately prepared before seeding or planting pines, hardwood sprouts seldom are a problem. But where good control of unwanted species was not achieved, additional treatment may be necessary.

Cutting the understory hardwoods creates a bigger problem than leaving them alone because cut trees sprout vigorously and grow much faster than uncut trees. If understory hardwoods require control, they should be killed with herbicide rather than cut.

Artificial Regeneration

Where there are not enough good pine seed trees to provide prompt and adequate natural regeneration, either planting or direct seeding may be used to establish pine stands on old fields or to convert poor-quality stands to pine. Since 1934, more than 140 million trees have been planted in Missouri, and shortleaf pine was the preferred species, especially in the Ozarks region. Many of the early plantings failed, but reliable planting techniques have been developed over the years for pine and, more recently, direct seeding of pine has also become practical.

Selecting and Preparing a Site

Whether a stand is to be established by planting or direct seeding, the site must be carefully selected and prepared to ensure success. Planting is too costly to try on sites not well adapted to pine. Where the black oak site index exceeds 65, hardwoods usually grow faster and should be favored over pine.[4] At the other extreme, where the site index is less than 45 for black oak, pines will seldom grow fast enough to repay conversion costs in a reasonable time. This is true of many typical post oak sites on broad ridges where soils are underlain by a dense fragipan. Also poor survival and growth will result where pines are planted on excessively drouthy sites such as "glades," gravelly alluvial soils along streams, or very rocky soils.

Outside the natural range of pine, planting sites must be selected even more carefully to assure success. Prairie soils contain more clay and often have poorer internal drainage than soils in the Ozarks Region. Because available winter moisture often becomes critical on "heavy" soils in north Missouri, survival and growth of planted pine has been better on north- or east-facing slopes, and better on any slopes than on nearly level land.

In most cases, excess hardwoods must be controlled to reduce competition for light and moisture and to permit maximum growth rates of the young pine trees. If hardwood control is postponed until after the pines are established, some trees will be damaged by foliage sprays.

The nature of the soil, amount of debris on the ground, number of hardwoods to be killed, cost of establishing the trees, and expected growth rates all must be considered in deciding whether pine should be grown on a particular area. Overall costs and returns usually dictate the feasibility of the operation. The landowner should concentrate efforts to convert poor hardwoods to pine on areas where total costs are reasonable and where pine offers the best chance for profit.

The need for and cost of preplanting treatment often determines the feasibility of planting or seeding. For example, eliminating dense stands of hardwood sprouts is possible but seldom practical. Economic considerations also may preclude conversion of pole-sized oak stands to pine; usually it is necessary to wait until the present trees can be sold at a profit before considering conversion to pine even on "pine" sites.

4. Shortleaf pine trees are not always present on sites where the forest manager suspects that pine would grow well. But black oak trees 40 to 60 years old occur on a wide variety of sites; therefore, it is convenient to discuss site quality for both pine and oak in terms of black oak site index.

Planting

Once they are well established on suitable sites, pine trees grow well and withstand the hot dry periods that can be expected in most growing seasons, but small trees are easily killed by careless handling before and during the planting operation. In a study of pine plantings on private lands, Dingle and Fletcher (1955) found that following good planting practices improved establishment success 25 to 30 percent. These practices included: (1) choosing and properly preparing a suitable site; (2) using good-quality planting stock; (3) planting trees correctly; and (4) providing adequate protection and care of the trees after planting. Failure to follow these practices usually resulted in poor survival or even failure of the planting.

Whether planting trees with a machine or by hand, several basic procedures must be followed (Limstrom, 1963):

1. Plant the tree slightly lower, never higher than it grew in the nursery.
2. Plant the tree upright and with the roots straight down, not doubled up or sharply bent. Trees with deformed root systems may survive, but growth rate will be poorer than on trees with normal root development. Cut off excess roots rather than cram them into the planting hole.
3. Pack the soil firmly around the roots to hold the tree upright.
4. Plant only one tree per spot.

Seedling Grades and Seed Source

In Missouri, shortleaf pine trees grown only one year in the nursery cost less and survive about as well as older trees (Chapman, 1944 and 1948). Planting stock should be at least four inches tall and have a minimum stem diameter of 3/20 inch at the ground line; smaller trees may not be worth planting (Limstrom, 1963). If roots are pruned to a six-inch length, the tops should be four to eight inches long. Seedlings 10 to 12 inches tall should have at least a 4/20-inch stem caliper. In a study of 20-year-old pine plantations in Missouri and Indiana, Clark and Phares (1961) found that planting only sturdy seedlings improved both survival and timber yields.

The planting stock should be grown from seed collected within 100 miles of the planting site or from a cooler climate (Rogers and Phares, 1962). Trees purchased from the Missouri Department of Conservation are grown at the George O. White Nursery at Licking, Mo., where seed of suitable origin is used. If planting stock is to be purchased from other nurseries, the source of seed should be checked; stock grown from seed collected more than 100 miles south of the proposed planting site should not be used.

Some General Planting Rules

Spring planting from about March 1 to April 15 is preferred in Missouri. Survival of fall-planted trees seldom is as good because of winter kill. Frost-heaving is common on fine-textured soils or where trees are planted on relatively bare ground as in old fields.

An 8-by-8 foot spacing usually is recommended for pine plantations in Missouri. This requires about 680 trees per acre. However, uniform spacing is not necessary. On forest sites it is better to plant the trees in spots free of brush and rocks where the seedling has a good chance to survive.

Machine Planting

Where they can be used, planting machines reduce the labor and cost of tree planting. Survival and growth of trees planted with machines is usually about as good as with hand planting. But rocky soils, steep slopes, logging debris, stumps and roots, and excessive amounts of brush make machine planting impractical. It may be cheaper to hand-plant areas smaller than one acre than to rent a planting machine.

On suitable sites, a three-man crew can plant about 1,000 trees per hour with a tractor-drawn tree planter. This is at least three times as efficient as hand planting. Good planting days in the spring are few, so planting machines should be used to speed up large planting jobs on rock-free soils.

Planting machines can usually be rented from the Missouri Department of Conservation, and the area farm forester can arrange to have a machine available. He also will assist in selecting the planting site, prescribe site treatment, the number of trees needed, and help train the planting crew.

Successful machine planting requires careful attention to details. If the soil is too wet, the packing wheels often pull trees out of the ground. Planting stock must be of uniform size and quality. A mixture of small and large trees is hard to plant properly. The roots of planting stock must be kept moist during the entire operation. Frequent checks must be made to see that trees are planted to the right depth and properly packed in the ground.

Hand Planting

Hand planting is generally used (1) when planting machines are not available, or (2) where the planting site is too steep, stony, gullied, or brushy as in most of the Ozark area, or (3) where the area is too small to justify machine planting. There are two general methods of hand planting. The slit method consists of making a slit in the ground with a planting bar, mattock, or spade, inserting the tree roots, and closing the slit both top and bottom. This method is faster than the hole method but is best suited to relatively stone-free soils. The side-hole method usually used in the Missouri Ozarks consists of digging a hole with a mattock or shovel, inserting the tree root, and packing the soil tightly around the roots (Limstrom, 1963).

Direct Seeding

With improved repellents to protect pine seed from birds, rodents, and insects, direct seeding now is a reliable way to establish pine stands. Depending on the amount of hardwood control needed, direct-seeding costs of $8 to $15 per acre (Brinkman and Phares, 1963) are from one-third to one-half those of the hand planting method generally required on Ozark sites. In most years, seeding will be about as successful as planting trees (Fig. 7).

Over a 14-year period, direct-seeded pine trees survived better and grew faster than planted pine of the same age (Phares and Liming, 1960). In a comparison of the development of direct-seeded with planted pine in New Jersey, Little and Somes (1964) found that seeded shortleaf pine developed well-distributed root systems whereas planted trees usually had intertwined roots and trees planted in slits had root systems developing only in one plane.

Figure 7. Dense stand of pine seedlings resulting from direct seeding. Overstory hardwoods were killed with herbicides. (F-518232)

Unlike planting, which must be completed in a period of about six weeks in the spring, direct seeding can be done from early December to about April 15 (Phares and Liming, 1961). Because direct seeding costs less than planting and results in faster growing trees, its use is expected to increase.

Within the species' natural range, any site where shortleaf pine normally will grow can be direct-seeded. Trials of direct-seeding pine outside the natural range have been limited, so extensive use of the techniques in other areas cannot be recommended at this time. For best results with direct seeding, plan to prepare the seeding site carefully, have adequate amounts of suitable seed available, and treat the seed with repellents before sowing.

Site Preparation

Because of the additional investment in seed and sowing costs, adequate site preparation is even more important on direct-seeded areas than where natural regeneration is expected. Excess hardwood trees and brush must be controlled. In dry years, a properly prepared seedbed can make the difference between success and failure of direct seeding. Where a thick layer of hardwood leaves is present, the seedbed should be prepared by prescribed burning in late November or early December. Burning this late would destroy the seed on areas where natural regeneration is expected. With this exception, site preparation is the same in both cases (see section on "Seedbed Requirements").

Seed Selection and Treatment

Only clean seed with at least 80 percent germinability is worth sowing, and it must be treated to repel birds and rodents. The recommended repellent is a blend of Arasan 42-S, a liquid suspension of thiram, and Endrin 50-W, a wettable powder. Thiram is a bird repellent and fungicide, and endrin protects against rodents and insects. A latex sticker is used to bind repellents to the seed. Powdered aluminum may be added to makc the seed flow evenly from the seeder (Seidel and Rogers, 1965).

Coating the seeds with repellents reduces germination somewhat but not enough to offset the protection value of the treatment (Seidel, 1963). Stratifying pine seed before spring planting hastens germination. After the seed has been stratified, it may be stored as long as 30 days at 38° F. without adverse affects.

Most trials of direct seeding in Missouri have shown consistently better results when unstratified repellent-treated seeds are sown between December and February. Seed sown between March 1 to about April 15 must be stratified as well as treated with repellents.

Seeding Methods and Rates

Sowing one-half to three-fourths pound of seed per acre (untreated dry-weight basis) usually gives satisfactory results. But the amount actually needed depends on germination percentage and size of seed in any particular lot (Seidel and Rogers, 1965).

For most operations in Missouri, seed is sown with cyclone seeders; 10 to 20 acres can be covered per man-day, and as many as four men can be used per seeding crew (Fig. 8).

For large seeding jobs, aerial sowing is faster and probably cheaper. Up to 1,500 acres per day can be sown with a fixed-wing plane, and about 2,500 acres with a helicopter.

Spot seeding is sometimes used for small areas where prescribed burning or disking is impractical. Less seed is used per acre, but only two to four acres can be seeded per man-day. Using a rake or a special seeding tool, the planter scrapes the litter from a spot about 18 inches across, drops about 10 seeds in the cleared spot, and presses the seed into the soil with his feet. Repellent-treated seed must be used to reduce losses to seedeaters.

Figure 8. Crew using cyclone seeders to sow treated pine seed. (F-518226)

Protection

Regardless of how they were established, well-stocked stands of pine have high potential value and must be protected from fire, grazing animals, insects, and diseases. High winds or ice storms sometimes cause local damage. Periodic examinations and prompt remedial measures may prevent severe losses in young stands. Older stands are less susceptible to damage from grazing animals and most insects, but fire and disease always are potential threats to survival and growth. In spite of these recognized hazards, pine stands can be grown to maturity in Missouri if reasonably good protection is provided.

Fire

Almost all forest fires in Missouri are man-caused and could be prevented. Woods-burning has been the traditional method for "controlling the brush" in hardwood stands to increase forage for livestock. With the closing of "open range" land, improved fire protection, and better markets for pine products, wide-ranging fires are not the problem they were 25 to 30 years ago. Now the major problem is the large number of fires that must be suppressed.

Most fires in Missouri burn relatively slowly and usually stay on the ground. Disastrous crown fires occur only in times of high hazard, especially where fuels are abundant. Only the litter layer burns in most fires, but this can become flammable soon after rains cease (Crosby, 1961).

Figure 9. Basal sprouts developing on young pine tree after the top was killed by fire. (F-518225)

Because young pines as large as three inches in diameter sprout freely after the tops are killed by fire, damage to these trees may be limited to lost height growth (Phares and Crosby, 1962) (Fig. 9). The hardwoods sprout even more vigorously after fires, however, so they

Figure 10. Stand of pole-sized pine trees killed by fire. (F-518224)

may offer more competition to the young pines than before.

Although larger pines do not sprout after the tops are fire-killed, the thick bark of older trees is resistant to moderate fires, and fire scars on the butts of damaged trees usually pitch-over without undue decay resulting. However, a severe fire will kill many larger trees and cause heavy losses (Fig. 10).

Insects

Larvae of pine tip moths (*Rhyacionia frustrana* Comst.) and (*R. rigidana* Fern.) often cause severe damage in Missouri shortleaf pine plantations. Two or three generations may develop each year. The larvae mine twig tips, causing deformed trees and loss of new height growth (Craighead, 1950). Although tip moths can be controlled with insecticides, chemical control is impractical under most conditions. After trees attain heights of 20 to 25 feet they are not seriously affected by tip moth larvae.

Trees weakened by drouth or damaged by logging operations or fire may be attacked and killed by the black turpentine beetle (*Dendroctonus terebrans* Oliv.) or the pine engraver beetles (Ips. spp.). Healthy trees also may be killed near areas where large populations of the beetles have developed in logging slash. Valuable trees such as those in seed production areas may be protected by application of BHC to the lower trunks.[5] Larvae of the redheaded pine sawfly (*Neodiprion lecontei* Fitch) and the loblolly pine sawfly (*N. taedae linearis* Ross) sometimes defoliate trees of all sizes, causing loss of growth and some mortality. These insects seldom have been of major importance in Missouri.

Diseases

Unlike the other southern pines, shortleaf is practically immune to fusiform rust (*Cronartium fusiforme* (A & K.) Hedc. and Hunt), but *C. quercuum* (Berk.) Miyabe ex Shirai *(C. cerebrum)* forms round galls on many trees. Fortunately, this rust seldom damages the main stem except on small trees. Another rust (*C. commandrae* Peck) has been found in one area of Missouri (Berry et al., 1961) and is reported to be locally important in northern Arkansas. Because susceptibility to gall rusts apparently is an inherited trait, badly infected trees in pine stands should be removed in early thinnings to reduce chances of their seedlings forming part of the next generation. Obviously, seed from such infected trees should not be collected for use in nurseries or for direct-seeding operations.

In recent years, root rot (*Fomes annosus* (Fr.) Cke.) has become a serious threat to shortleaf pines, especially those growing in plantations on old-field sites. First reported in Washington County in 1958 (Jones and Bretz, 1958), it was found to be widespread in thinned stands of southern Missouri in 1962 (Berry and Dooling, 1962). The fungus damaged fewer trees in natural pine stands than in plantations. Other research has shown that the incidence of root rot infection is very significantly related to low organic matter, low silt content, high clay content, and sparse grass cover (Froelich et al., 1966). This may help explain why plantations on old-field sites are more apt to become severely infected than those growing on forest sites.

Root rot infections may develop after a healthy pine plantation is thinned for the first time (Fig. 11). Airborne spores of the fungus that fall on freshly cut stump surfaces germinate promptly. The fungus grows down the stump and out along the roots where they contact roots of healthy trees, spreading the infection. Once established in the soil, the fungus may survive for 50 years or more. No feasible soil treatment is known.

The chance of new infections can be greatly reduced

5. Benzene hexachloride. Apply as 0.5-percent solution in fuel oil to a height of 8 to 10 feet.

Figure 11. Many pine trees in this plantation were killed by root rot *(Fomes annosus).* (F-518231)

by immediate treatment of tree stumps after each thinning in pine plantations (Berry, 1965). Dusting tree stumps with a borate compound (such as Borateem) or applying a 10-percent Borateem-water solution gives good control. This treatment costs about $2.50 per hundred trees. Stump treatment is not warranted once the disease is established in a stand because its spread cannot be prevented.

Natural stands and plantations on forest sites probably need no stump treatments. Limiting the frequency of thinnings in old-field plantations reduces opportunity for new infections.

Other Hazards

Animal Damage

Although cows and horses seldom eat pine trees, old-field plantings or seedings may be heavily damaged by trampling. Goats and sheep must be excluded from young pine stands, at least until the crowns are beyond reach of these animals. Entire plantations may be destroyed by hogs rooting for grubs in grassy areas.

Mice, squirrels, insects, and birds consume or destroy most of the pine seed produced in years when the seed crop is poor. Thus, successful natural regeneration of pine may be limited to years of bumper seed crops.

Climatic Injuries

Occasionally, glaze damage is severe in pine stands. Young trees may be uprooted and branches may break when ice accumulates.

Similarly, high winds may uproot trees, especially when soils are saturated. Such trees usually can be cut and sold. However damage seldom is widespread or important enough to limit commercial production of pine.

Basic Management Guidelines

Within and near its natural range in Missouri, shortleaf pine should be managed in essentially pure stands on sites where the black oak site index is 45 to 55, and favored in oak-pine stands where site index is 55 to 65. On suitable sites, the proportion of pine in oak-pine stands often can be increased by selling or killing unwanted hardwood trees in the first thinning operations. In older stands where enough pine seed trees are present, natural pine regeneration should be sought toward the end of rotation. Or, the areas may be clearcut and direct-seeded to pine.

On those Ozark sites where black oak site index exceeds 65, oaks will make better height growth than pine and conversion to pure pine stands may not be practical. Stands on such sites should be managed to favor northern red oak, black oak, scarlet oak, and pine in that priority order. These sites will produce good-quality oaks, and the costs of maintaining pine in the main stand may become excessive except where the pines can be left growing in groups.

Shortleaf pine and any oaks growing with it should be managed in even-aged stands because all the species of major value are relatively intolerant of shade. Silvicultural rotation ages for pine and black oak are about the same, 80 to 90 years, but the economic rotation for pine is somewhat shorter, especially for stands growing on old-field sites. Scarlet oak, an important component of oak-pine stands in the southeastern Ozarks, should be cut at 70 to 75 years or earlier. In such stands, the scarlet oaks may be harvested before the pine and treatments applied to favor pine regeneration.

Because white oak requires at least 120 to 150 years to reach sawlog size on pine sites, it is not well suited for growing in mixture with pine. Similarly, species such as hickory and blackgum are of secondary importance on pine sites because of slow growth rates and limited commercial value. A few trees should be left, however, because of their food value for wildlife.

Although natural stands of shortleaf pine almost always include some trees of other species, discussion of volume growth and yield in this bulletin assumes the management of essentially pure, well-stocked stands. Most data are for pine stands where all other species had been removed.

Growth and yield of understocked stands or mixtures of pine and hardwoods will be less than for well-stocked pine stands. The same management principle applies, however, in that thinnings and stand improvement operations should provide adequate growing space for the best trees in the stand.

Total cubic volume growth for pine stands varies little over a wide range of stocking density, but both understocking and overstocking are undesirable. Although individual trees grow rapidly in understocked stands, volume growth per acre is less than in well-stocked stands. Overstocking results in slower growth per tree, volume lost through natural mortality, and a longer rotation to produce large trees.

Stocking should be maintained at levels where the growing space is fully utilized, the rotation is minimized, and few trees are lost because of shading or crowding. Even in understocked stands, McGinnes (1963) found that the physical properties of mature wood produced in rapid-growing pines were very similar to those of slow-growing trees. Thus, good pine management should provide as many fast-growing trees as possible within the limits of desirable stocking density. This objective is achieved by means of periodic thinnings.

In general, thinning frequency and the stocking to be left depend on the age, growth rate, and size of trees in the stand. Because pine stands growing on old-field sites present problems, however, the management of such stands differs in some respects from that of stands growing on forest sites. Consequently, suggested management guides for old-field stands and for forest stands are presented separately in the following chapters.

Management on Old-Field Sites

Most pine plantations are found on old fields where planting was easier than on forested sites because the soils contain less rock, and hardwood brush and roots seldom are problems. But previous agricultural use and erosion on old fields has depleted the soil in varying degrees; natural pruning is delayed because of the wide spacing of trees in plantations, especially where initial stocking was poor; and tipmoth damage often is severe in isolated plantings, resulting in short trees with poor form.

Direct-seeded and natural pine stands on old-field sites may share some of these problems. If adequate initial stocking is achieved, natural pruning will occur earlier than in planted stands, but the same general management plan should be followed.

The greater hazard of *Fomes annosus* infection on old-field sites is the major reason for modifying management. The cost of treating stumps of cut trees to protect the rest of the stand reduces profits from thinnings. This limits the number of profitable thinnings and usually means that the trees will not be grown long enough to produce large sawlogs. In spite of these problems, however, shortleaf pine is the best species to plant on old fields in or near its natural range.

Pruning

Natural pruning is slow in old-field shortleaf pine plantations. Dead branches may persist for 10 to 12 years or longer, and landowners often are concerned about the "rough" appearance of young stands. By the time well-stocked plantations are 30-years old, however, natural pruning will have removed most lower branches from the trees (Fig. 12). It generally is better to cut excessively limby trees in the first thinning and then decide whether pruning is needed.

Pruning is expensive, and the investment may not pay off in increased value of the products sold. If done at all, pruning should be limited to perhaps 100 to 150 selected trees per acre, the potential crop trees. Branches should be cut (with a saw) flush with the bole; this stimulates pitch flow and subsequent healing. Pruning high enough to provide one clear 16-foot log generally is adequate for shortleaf pine on average sites. About eight man-hours are required to prune 100 trees per acre to a 17-foot height.

Thinnings and Harvest Cutting

To diminish chances of introducing *Fomes annosus* into old-field pine stands, thinnings should be deferred as long as possible and limited to those absolutely necessary to maintain good diameter growth. Stumps should always be treated with borax (see disease section). The first thinning on most sites should be made when the stands are from 30 to 35 years old. Post and poles can be harvested at this time (Fig. 13), leaving 65 to 70 square feet of basal area per acre.

At age 45 to 50 if tree sizes and markets permit, the second and last thinning should be made leaving about 80 square feet of basal area per acre.

Roach (1958) reported that a mature old-field stand of shortleaf pine did not respond to thinning at age 90. He recommended keeping stocking high in such stands for better volume growth and for controlling the understory hardwoods.

Although a 45- to 50-year rotation may be best on poor sites, highest net returns from plantings on most old field sites probably will be received when the trees can be sold for large poles or sawlogs. On average sites, this will be when the trees are 60 to 65 years old. If diameter growth is still good at this age, however, the stand need not be cut.

Regeneration Cutting

If growth rates have been satisfactory and root rot has *not* become established in the stand, another crop of

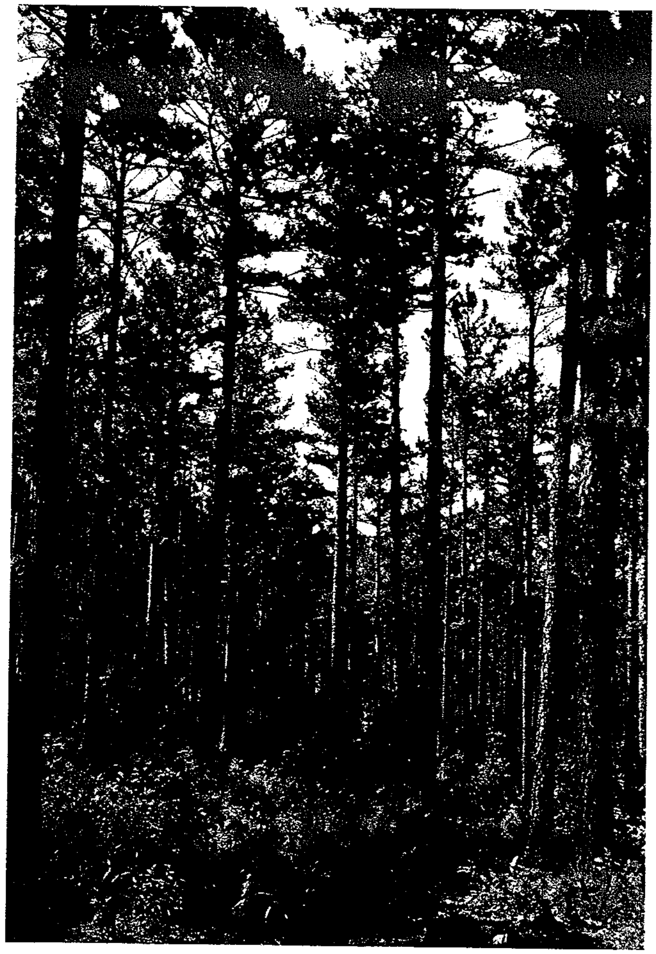

Figure 12. Natural pruning has removed most lower branches in this 30-year- old plantation. (F-518222)

Figure 13. Posts and poles harvested from pine plantation. (F-502350)

pine may be grown. If enough advanced pine reproduction is present to form the new stand, the mature trees may be cut and competing understory hardwoods controlled as necessary.

Where reproduction is inadequate, the stand can be clearcut and direct-seeded, or a seed-tree cutting can be made at age 60 to open up the stand and encourage seed production. About 25 large well-distributed trees should be left per acre and, where necessary, excessive amounts of hardwood in the understory should be controlled with herbicides. If necessary, a light prescribed burn to reduce hardwood litter can be made, preferably in the summer or early fall of a good seed year or before direct seeding. The balance of the mature trees should be harvested as soon as enough regeneration is obtained. Again, stumps must be treated to prevent introduction of root rot.

Yields

Most pine plantations in Missouri and nearby states are 30 years old or less, so yield data are not available for plantations grown to maturity. However, growth and yield is expected to equal or exceed that obtained on forest sites (see Table 1 in next section). Total volume production in some plantations has been from 10,000 to 12,000 board feet per acre in 29 years. This is more than that shown for natural stands because of more uniform initial stocking, less hardwood competition, and earlier management to maintain good growth rates.

Management on Forest Sites

Whether planted, direct-seeded, or of natural origin, pine trees generally have higher quality on forest sites than on old fields. Self-pruning occurs earlier because of competition with other trees of the same or greater height, and tipmoth populations seldom become epidemic. There is less danger of *Fomes annosus* infection, so thinnings are more profitable because stumps need not be treated. Longer rotations may be used to produce large sawlogs.

Thinnings reduce the capital investment in growing stock, and the periodic returns recover accumulated management costs. Poor-quality trees are cut and sold while still small, so volume growth is concentrated on the better trees. These are worth more when sold in later thinnings, and faster growth per tree results in a shorter rotation.

Well-stocked pine stands on average sites can be thinned as early as age 25 for posts and small poles, and at 8- to 10-year intervals thereafter. The interval between thinnings need not be constant, of course, and the volume and size of trees cut can be adjusted to fit available markets.

To achieve maximum returns in the shortest time, however, adequate growing space must be provided for the crop trees, and the number of trees lost through mortality should be kept to a reasonable minimum by periodic thinnings. The average growing space available per tree depends largely on stand density, but the amount of understory competition also affects growth rate.

Effect of Stand Density on Growth Rate and Tree Quality

Most thinning studies have shown that the gross volume produced in unthinned pine stands is about the same as in thinned stands unless too few trees are left for full site use. On the Sinkin Experimental Forest near Salem, Mo., this generally was true for pine stands thinned to various stocking levels at ages 30 to 40.[6] No statistically significant differences in volume growth were found in the first 10-year period (Brinkman and Rogers, 1965). At age 30, thinning to 70 square feet of basal area per acre generally resulted in best growth and yield through age 40 (Table 1).

In the five-year period following the thinning at age 40, however, the unthinned and lightly thinned stands added significantly more cubic-foot volume than stands thinned to either 50 or 70 square feet of basal area per acre (Table 1). Board-foot volume growth was significantly less in the "50" stands than in the "110" and "check" stands. Ingrowth in cubic feet was negligible, and board-foot ingrowth even in unthinned stands was only 250 feet per acre in this five-year period. This suggests that the basal area to leave after thinning should increase with stand age and average tree size to maintain reasonably complete stocking.

Thinnings may have little effect on the diameter growth rate of the largest trees in even-aged stands. At age 45, the 100 largest trees per acre in unthinned stands had the same average d.b.h. (10.7 inches) as similar trees in stands thinned twice to 110 square feet of basal area. These average diameters were only 0.5-inch less than comparable trees in the "70" and "90" stands.

When all trees in the stands are considered, however, the average d.b.h. increase was only 1.5 inches in 15 years

6. Pine stands in this area were thinned at age 15 to leave about 600 trees per acre. Most hardwoods were cut or girdled. This early treatment probably increased the average size of trees cut at age 30 but the net affect on growth and yield by age 40 is uncertain. The above discussion of volume growth at various stocking levels does not consider the earlier thinning.

TABLE 1--PRODUCTION; GROWTH; AND YIELD (INCLUDING MORTALITY) PINE STANDS FROM AGE 30 TO AGE 45. STANDS THINNED AT 30 AND 40 YEARS: ALL HARDWOODS WERE CONTROLLED.

Age (years)	Item	Stand density (basal area left per acre) 50	70	90	110	Check
		Cubic-foot volume 1/				
30	Yield	1,220	960	725	220	--
	Left	900	1,230	1,535	1,785	2,290
30-40	Growth 2/	855	990	930	955	810
40	Yield 2/	675	780	690	635	30
	Left	1,080	1,440	1,775	2,105	3,070
40-45	Growth 2/	355	515	630	730	910
	Mortality	30	0	0	15	60
45	Volume	1,405	1,955	2,405	2,820	3,920
	Total production 3/	3,330	3,695	3,820	3,690	4,010
		Board-foot volume 4/				
30	Yield	2,545	1,670	1,430	230	--
	Left	3,025	4,080	5,090	4,740	6,160
30-40	Growth 2/	5,075	5,950	5,570	5,710	4,825
	Yield 2/	2,915	3,290	2,690	1,715	50
40	Left	5,185	6,740	7,970	8,735	10,935
40-45	Growth 2/	1,820	2,710	3,390	3,975	4,815
	Mortality	125	0	0	30	90
45	Volume	6,880	9,450	11,360	12,680	15,660
	Total production 3/	12,465	14,410	15,480	14,655	15,800

1/ Gross peeled volume in cubic feet to a three-inch top (d.i.b.)
2/ Includes mortality.
3/ Sum of yields at ages 30 and 40 plus mortality and volume left at age 45.
4/ Gross volume in board feet to a five-inch top (d.i.b.) International one-fourth-inch rule.

in unthinned stands compared with 3.3 inches in the "70" stands and 2.7 inches in the "90" stands. Selective thinnings to remove small trees and poor-quality trees had shortened the time needed to produce large products because the trees left developed and maintained good crowns.

The quality and value of products removed from pine stands in the first thinning depended largely on the number of trees cut. Value per tree was about the same. In the second thinning of the managed stands, however, about 80 percent of the products in the "50" and "70" stands consisted of poles and sawlogs, while posts made up nearly 60 percent of the total yield in the "110" stands. So the average tree cut in the "50" and "70" stands at age 40 was worth twice as much as in the "110" stands. When the next thinning is made, greatest return per tree is expected from stands thinned to 90 square feet of basal area per acre.

Because a given volume in large trees with long straight boles is worth more than the same volume in small trees, managed stands can be expected to yield more dollar returns and at least as much total volume over the rotation. With each successive thinning, value per tree cut increases, and the final harvest will consist of high-quality, high-value trees.

Effect of Understory Hardwoods on Pine Growth

On the rocky soils of the Missouri Ozarks, pine trees often stop growing during the frequent summer drouths. These drouths affect young pines more than oaks because the pines normally continue to grow all summer whereas the oaks complete their height growth by July (Johnson, 1941). So one reason for making thinnings and improvement cuttings in pine stands is to reduce competition for available soil moisture. The usual practice has been to leave hardwoods unless their crowns compete directly with the pines. A recent study shows that eliminating *all* hardwoods in pine stands results in increased volume growth (Fig. 14).

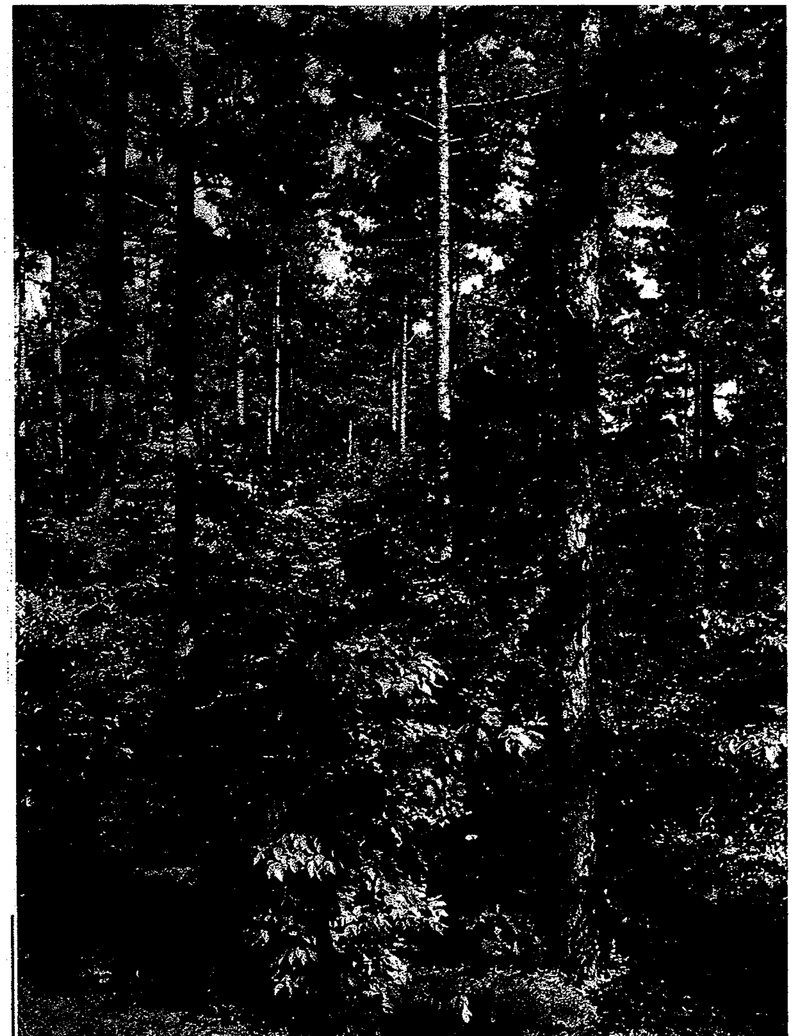

Figure 14. Understory hardwoods such as these may reduce the volume growth of pine stands. (F-518230)

During the first 10 years after hardwood control, basal area and volume growth increased 40 percent in both unthinned pine stands and stands thinned to 70 square feet of basal area per acre at age 30 (Rogers and Brinkman, 1965). These growth differences were measured during a period of below-normal rainfall, and results must be interpreted with this in mind. During the next five years, summer rainfall was about normal, and growth differences were less apparent. Volume growth was 9 to 15 percent more in pine stands without hardwoods than in the other stands.

This indicates that small hardwoods significantly reduce the growth of pine stands only in dry years when the soil moisture supply becomes exhausted. Although eliminating all hardwoods in pine stands results in increased volume growth, the treatment is expensive and is not recommended as a routine practice.

Hardwood control in pine stands is usually adequate when: (1) hardwoods two inches and larger at the ground line are killed with injector-applied herbicides, and (2) pine stocking levels are maintained high enough to form a reasonably complete canopy. Where a hardwood understory has developed in stands at the time of the regeneration cutting, the larger hardwoods should be killed with herbicide and a prescribed burn made if necessary to prepare the seedbed.

Stand Volume Estimation

Stand volume can be determined in several ways and with varying degrees of precision. For high-value trees, a complete stand inventory may be desired, but some sampling technique is generally used for pine. When a timber sale is planned, the usual procedure is to measure the merchantable heights, diameters, and volumes of trees on sample plots and expand these data to find volume per acre.

For many management purposes, however, present stand volume can be estimated adequately by using stand volume equations. Stand measurements required include basal area per acre, height of the dominant trees in the stand, and average tree diameter based on angle-count or point sampling counts.

Equations developed for even-aged pine stands in Missouri provide direct estimates of the merchantable stand volume in cubic feet and board feet per acre (Brinkman, 1967). Site quality is not a variable in the equations.

Stand Volume Equations

Basal area per acre (B) may be determined from 10 or more sample points, using a wedge prism or angle gauge with a factor of 10. Only those trees with a d.b.h. larger than the minimum specified for the volume measurement involved should be considered: 4.6 inches for cubic volume and 6.6 inches for board-foot volume. To determine board-foot volume, these larger trees must be counted at each sample point so that mean tree diameter (D) can be computed; for convenience, a 1/20 acre circular plot can be used with a rangefinder set at 26-⅓ feet to check borderline trees. Knowing total basal area and number of trees per acre, D to the nearest inch can be computed with the aid of a standard basal area table. Total height (H) of at least five dominant trees in the stand must be determined with an accurate hypsometer.

Merchantable cubic-foot volume to a three-inch top diameter inside bark can be found using only B and H.

For example, assume a stand where B is 70 and H is 60. Volume is determined as follows:

$$\begin{aligned} V &= 0.323\ (B \cdot H) + 92.18 \\ &= 0.323\ (70 \times 60) + 92.18 \\ &= 1{,}450 \text{ cubic feet per acre} \end{aligned}$$

Merchantable board-foot volume to a five-inch top d.i.b. can be computed in a similar manner, but another variable, D, is needed. Assuming the sample data show that B is 90, H is 70, and D is 12 inches, the computation is:

$$\begin{aligned} V &= 0.0214\ (B \cdot H^2) - 79.5\ H + 624\ D - 247 \\ &= 0.0214\ (90 \times 4900) - 79.5\ (70) + 624\ (12) - 247 \\ &= 11{,}113 \text{ board feet per acre} \end{aligned}$$

Round off this value to 11,100 board feet.

To simplify use of the board-foot equation, a table has been prepared for representative combinations of B, H, and D (Table 2.) By interpolating in the table as necessary, the forest manager can easily find the present volume of a pine stand.

Growth Predictions

The stand volume equations and Table 2 also can be used to predict volume growth for short periods when expected increments in B, H, and D are known. Obviously, the growth predictions will be no more accurate than the estimates of changes in these variables.

In Missouri shortleaf pine stands, annual basal area increment ranges from 2 to 4 square feet per acre, depending on stocking density and age of trees. On average sites height growth will average a foot per year between ages 25 and 40, 0.8 foot from age 41 to 60, and 0.5 foot in older stands. Mean d.b.h. growth often is about two inches with every 10-foot increase in total height, but this depends on stand density. In unthinned stands, d.b.h. growth may be as low as 1.3 inches per 10-foot height increase.

To illustrate one method of growth prediction, assume a 40-year-old shortleaf pine stand with 90 square feet of basal area per acre, a mean d.b.h. of 10 inches, and dominant trees 60 feet tall. The present volumes computed with the equations are 1,836 cubic feet and 8,150 board feet per acre. During the next five years, it is estimated that the stand will add about 15 feet of basal area, 5 feet in total height, and one inch in mean d.b.h. When these increases are added to the present stand values, the expected volumes at age 45 become 2,296 cubic feet and 10,800 board feet per acre. This indicates a volume increment of 460 cubic feet or 2,600 board feet in five years.

An indication of expected board-foot volume growth also can be obtained by using Table 2. Interpolation nearly always is necessary. For the stand described in the previous example, the original volume shown in Table 2 is 8,150 board feet. In five years this would increase to about 10,700 board feet per acre, approximately as computed above.

Predicted Growth and Yield of a Managed Stand

The growth rate and volume yield of pine stands are related to site quality. Trees on poor sites grow slower and are not as large at the same age as trees on good sites. Regardless of site quality, however, dollar earnings over the rotation are usually largest where periodic thinnings are made to provide intermediate returns and maintain adequate growing space per tree.

Data for managed even-aged pine stands in Missouri indicate that the ideal basal area to be left after each thinning increases with stand age and average tree size. The basic requirement is that thinnings should leave enough trees to occupy most of the available crown-growing space and still provide enough room for the better trees to develop. General guidelines have been developed for desirable basal area stocking and volumes at various ages.

Applying these guidelines to a model managed pine stand, a table was developed to show what growth and yields can be expected on average pine sites in Missouri (Table 3). Cubic-foot volumes shown in the table are for all trees 4.6 inches d.b.h. and larger, including those considered to have board-foot volume. In young stands, most trees will be sold as posts or poles instead of sawlogs. The model assumes thinnings at 10-year intervals beginning at age 30 to provide periodic returns over an 80-year rotation where the site index is about 60. No claim is made that this example represents optimum management for pine; rather, the growth and yields shown are the best available estimates of what could be achieved under the specified conditions.

Growth rate and yields to age 50 are based on managed young stands that were thinned twice.[7] A few older stands were available to verify growth predictions. But most volume estimates for older stands were derived with the stand volume equations.

In the model stand, enough volume is removed in each thinning to provide an operable cut. The first two thinnings will remove any poor-quality trees in the main stand plus smaller trees salable as posts or small poles. In succeeding thinnings, all trees cut will qualify for poles or sawlogs and posts may be cut from upper log sections.

7. See footnote 6, page 20.

TABLE 2--BOARD-FOOT VOLUME PER ACRE OF SHORTLEAF PINE STANDS IN MISSOURI IN RELATION TO BASAL AREA, HEIGHT OF DOMINANT TREES, AND AVERAGE TREE DIAMETER[1/]

Basal area per acre (sq. ft.)	Average diameter (inches)	Height of dominant trees (feet) 40	50	60	70	80	90
		Board Feet					
70	8	3,950	4,500	5,350	6,500	7,950	9,700
	9	4,600	5,150	6,000	7,150	8,600	10,350
	10	5,200	5,750	6,600	7,750	9,200	10,950
	11	5,850	6,400	7,250	8,400	9,850	11,550
	12	6,450	7,000	7,850	9,000	10,450	12,200
	13	7,100	7,650	8,500	9,650	11,100	12,800
	14	7,700	8,250	9,100	10,250	11,700	13,450
	15	8,350	8,900	9,750	10,900	12,300	14,050
	16	8,950	9,500	10,350	11,500	12,950	14,700
	17	9,550	10,150	10,800	12,100	13,550	15,300
	18	10,200	10,750	11,600	12,750	14,200	15,950
90	8	4,650	5,600	6,900	8,600	10,700	13,150
	9	5,250	6,200	7,500	9,200	11,300	13,800
	10	5,900	6,800	8,150	9,850	11,950	14,400
	11	6,500	7,450	8,750	10,450	12,550	15,050
	12	7,150	8,050	9,400	11,100	13,200	15,650
	13	7,750	8,700	10,000	11,720	13,800	16,300
	14	8,400	9,300	10,650	12,350	14,450	16,900
	15	9,000	9,950	11,250	12,950	15,050	17,550
	16	9,650	10,550	11,900	13,600	15,700	18,150
	17	10,250	11,200	12,500	14,200	16,300	18,800
	18	10,900	11,800	13,150	14,850	16,950	19,400

Basal area per acre (sq. ft.)	Average diameter (inches)	Height of dominant trees (feet) 40	50	60	70	80	90
		Board Feet					
110	8	5,300	6,650	8,450	10,700	13,400	16,600
	9	5,950	7,250	9,050	11,300	14,050	17,250
	10	6,550	7,900	9,700	11,950	14,650	17,850
	11	7,200	8,500	10,300	12,550	15,300	18,500
	12	7,800	9,150	10,950	13,200	15,900	19,100
	13	8,450	9,750	11,550	13,800	16,550	19,750
	14	9,050	10,400	12,200	14,450	17,150	20,350
	15	9,700	11,000	12,800	15,050	17,800	21,000
	16	10,300	11,650	13,450	15,700	18,400	21,600
	17	10,950	12,250	14,050	16,300	19,050	22,250
	18	11,550	12,900	14,700	16,950	19,650	22,850
130	8	6,000	7,700	9,950	12,800	16,150	20,100
	9	6,650	8,350	10,600	13,400	16,800	20,700
	10	7,250	8,950	11,200	14,050	17,400	21,350
	11	7,900	9,550	11,850	14,650	18,050	21,950
	12	8,500	10,200	12,450	15,250	18,650	22,600
	13	9,150	10,850	13,100	15,900	19,300	23,200
	14	9,750	11,450	13,700	16,550	19,900	23,850
	15	10,400	12,100	14,350	17,150	20,550	24,450
	16	11,000	12,700	14,950	17,800	21,150	25,100
	17	11,650	13,350	15,600	18,400	21,800	25,700
	18	12,250	13,950	16,200	19,050	22,400	26,350

1/ Based on regression equation: $V = 0.0214\,(B \cdot H^2) - 79.5\,H + 624\,D - 247$ where V is gross board-foot volume (Int. 1/4" rule) to a five-inch top (d.i.b.), B is basal area in square feet per acre, H is mean total height of the dominant stand, and D is diameter of the tree of average basal area. Volumes rounded to nearest 50 board feet per acre.

TABLE 3--COMPOSITE MODEL OF GROWTH AND YIELD (INCLUDING MORTALITY) PER ACRE FOR A MANAGED SHORTLEAF PINE STAND ON SITE INDEX 60, THINNED FIRST AT AGE 30 AND THEN AT 10-YEAR INTERVALS, WITH THE FINAL HARVEST AT AGE 80

Age when thinned	Basal area	Volume		Number of trees
	Sq. ft.	Cu. ft. 1/	Bd. ft. 2/	
		TOTAL STAND		
30	140	2,200	5,600	625
40	110	2,300	9,900	225
50	125	2,800	15,000	150
60	135	3,250	17,000	115
70	135	3,300	19,000	85
		CUT STAND		
30	70	950	1,600	400
40	20	500	1,900	75
50	20	500	2,200	35
60	25	600	2,500	30
70	25	500	2,300	20
80	130	3,500	20,000	65
		RESIDUAL STAND		
30	70	1,250	4,000	225
40	90	1,800	8,000	150
50	105	2,300	12,800	115
60	110	2,650	14,500	85
70	110	2,800	16,700	65

1/ Merchantable volume of trees 4.6 inches d.b.h. and larger to a three-inch top diameter inside bark.
2/ Volume (Int. 1/4-inch rule) of trees 6.6 inches d.b.h. and larger to a five-inch top diameter inside bark.

In 70 years, predicted gross yields from thinnings total 3,050 cubic feet or 10,500 board feet per acre. The harvest cut at age 80 will yield an additional 3,500 cubic feet or 20,000 board feet. So estimated total yields over the rotation are 6,550 cubic feet or 30,500 board feet per acre.

These gross volumes could be reduced by mortality unless the dead trees are harvested promptly. In managed stands, relatively few trees will die because of suppression, so the major causes of mortality would be ice storms or high winds. If these should occur, the volume in dead trees will often be enough to warrant salvage cuttings. Of course, lightning, disease, or insects may kill isolated trees; these are not worth harvesting, but the volume loss should be small.

If the stand is grown to age 80, the average d.b.h. will be at least 19 inches and some trees probably will be 24 inches d.b.h. Trees this large are valuable, of course, but they must bring premium prices to justify growing them. Taxes, interest on the investment, and the inherent risk of major loss through storms all must be considered. In some cases at least it will be more profitable to use a shorter rotation and cut the stand for large poles and sawlogs.

The rotation actually chosen is based on current and expected values and costs, but the values are not always expressed in dollars. On public forest lands, for example, some stands may be grown for 90 years or longer simply because people like to see stands of large trees. In these cases, the aesthetic values are assumed to exceed current market value. But on commercial forest lands and to a degree on public lands, the forest manager tries to harvest stands when they become financially mature. A discussion of the values of costs and yields and a basis for determining financial maturity are provided in the following chapters.

Markets

Product prices and available markets exert a strong influence on the forest owner's interest in timber management. Markets for relatively small trees are especially significant because they enable the forest owner to make intermediate cuts at small out-of-pocket costs or even at a profit. Shortleaf pine in Missouri may be cut for three principal products: lumber, pulpwood, and posts and poles.

The total harvest of pine timber in Missouri is about equal to that estimated as "desirable" (Gasner, 1965a). The "desirable" cut assumes that there should be a reasonably even distribution of age classes of trees in the state to meet future needs for products. However, all size classes of pine are not being harvested at the same rate. The actual cut of sawtimber, equivalent to 52,000 cords, exceeds the desirable cut of 34,000 cords. For pole timber (trees five to nine inches in diameter), the actual cut of 8,000 cords is much less than the desirable cut of 24,000 cords. Thus there now is a surplus of small trees in Missouri that could be used for posts, poles, and pulpwood without risk of future shortages.

Lumber

Since the early 1900's, pine has been widely used for construction lumber. The initial harvest of old-growth pine provided framing, ceiling, and flooring for building the Midwest and developing the Prairie States. Lumber continues to be the major product outlet for pine, but it comprises only a small portion of the total lumber used in Missouri.

On private land, stumpage buyers usually make lump-sum purchases, but log-scale and lumber-scale purchases are becoming more common. Although quality differences are seldom recognized in pine, the highest prices are paid for large trees or where volumes per acre are high.

In the Ozark Region, prices of privately owned pine stumpage during 1966 ranged from $15 to $28 per thousand feet log-scale and averaged about $20 (University of Missouri, 1966). Scattered pine trees on National Forest timber sales currently sell for about $15 per thousand feet. In one stand with a high per-acre volume, pine stumpage brought $27.

Most shortleaf pine is used for building construction. But because of its relatively fine texture and excellent machining quality, pine also is suitable for factory-grade lumber. A better market for this could be developed. For example, furniture manufacturers in the state prefer Missouri-grown lumber for certain components, but often buy lumber from the South because Missouri lumber is not available when needed.

Pulpwood

Softwood pulpwood use in the nation has increased six-fold since 1920 and is now second only to lumber in volume of forest products cut (U.S. Forest Serv., 1965a). Furthermore, it is expected to double in 25 years. In Missouri, even though the pine resource is increasing substantially in area, tree size, and volume, pine pulpwood production is small; in 1964 it was only 1,206 tons, a little more than 2 percent of the total pulpwood output in the state (Gasner, 1965b).

Manufacturing capacity for all kinds of paper is expanding, either by additions to present mills or construction of mills at new locations. Competition for wood supplies is increasing. Whether or not a pulpmill is constructed in the state, more firms such as the new pulpmill at Wickliffe, Ky., will be drawing on Missouri-grown trees for part of their wood supply. The outlook, therefore, for future sales of pulpwood by landowners generally appears favorable. A pulpwood market will permit landowners to recover costs of improvement and thinning in young stands of relatively small-sized trees.

Posts and Poles

The use of pine posts treated with wood preservative increased rapidly after World War II and is continuing to increase partly because of the shortage of farm labor for post replacement. Development of the engineered pole-type building, in which pressure-treated pine poles 12 to 25 feet long form the structural members, is providing further expansion of the post and pole market. Increased production of piling and long poles offers the possibility of even higher returns per unit of wood for the landowner.

Posts and poles are cut to usable length and delivered to concentration yards where they are debarked, smoothed by a rosser, air-dried, and then treated with a wood perservative. Posts usually range from 2.5 to 7 inches inches in diameter at the small end and from 7 to 10 feet long. Poles are four to eight inches in diameter at the small end and 12 to 35 feet long. Typical prices of the commonly used sizes of unpeeled pine post and poles delivered to concentration yards during 1966 are shown in Table 4. Stumpage prices usually are about 30 percent of those shown.

The presence of a market for small posts offers a real opportunity to make profitable early thinnings. Small posts, sold by the piece, may bring a larger return to the seller than products sold by volume units. For example, 100 posts three inches in diameter at the small end and 7 feet long, if sold as stumpage for $0.07 each, would return $7 to the owner. Their volume is 0.6 cord. If sold as pulpwood at a stumpage price of $5 per cord, they would return $3. But pieces five to seven inches in diameter would bring less as posts at $0.10 to $0.20 each than as pulpwood at $5 per cord. Larger pieces, however, because of high unit prices, usually return greater receipts as posts or poles than if sold for other products. When markets for more than one product exist, the forest owner should consider the potential total returns from each alternative before deciding which product or combination of products will be the most profitable.

TABLE 4--TYPICAL PRICES FOR SELECTED SIZES OF POST AND POLES DELIVERED TO PEELING PLANT, 1966 1/

Diameter (inches)	Length (feet)	Price per piece	Diameter (inches)	Length (feet)	Price per piece
2.5	7	$0.08	6	12	.75
3	7	.20	6	14	.85
5	7	.25	6	16	1.15
3	8	.20	6	18	1.60
5	8	.30	6	20	2.00
4	10	.30	6	25	2.75
6	10	.55	7	30	5.00
4	12	.40	7	35	6.25

1/ Stumpage prices are about one-third of delivered prices.

Is Pine Management Profitable?

Forest land is not always acquired to earn money by growing trees. Some people buy land for recreation such as hunting or nature study, or to have a place to get away from the stresses of life. Owners may be interested chiefly in a rural setting for retirement; or pride of ownership may be the controlling motive. Often an element of speculation for mineral values or for other land uses is present. The following discussion is aimed primarily at the forest landowner who is interested in growing crops of shortleaf pine. But even owners with other objectives still might like to know what revenues are being foregone by not managing and harvesting their timber.

Records of past costs and incomes offer only limited guidance for timber management. Few records have been compiled over a long enough time to suggest future net income potential. As a minimum, it is presumed, a timber grower wishes to know the relationship of costs to revenue—that is, which of several possible investments in a stand will return the most net revenue.

Obviously, a simple cost-benefit ratio without adjustment for time does not account for accrued interest during the period between investment and pay-out. Available funds may be invested in several places, so an opportunity cost is also involved. Money spent to improve a stand of timber might have been used to buy savings bonds or to invest in another sort of business. Investment in a stand of timber, therefore, is a major cost of growing trees. Further, the amount of the investment and the length of time it is held vary substantially among management alternatives. Because time is a major variable in forest investments, discounted net worth (DNW)[8] is often used to estimate profitability. The DNW approach is a systematic way to evaluate long-term high or uncertain investment opportunities.

Computation of DNW requires the assumption of an interest rate or discount rate. Values must be compounded because funds are tied up for longer than a year. The rate selected has a profound effect on the result. When an investor is able to state a rate of return acceptable to him, DNW may be a satisfactory standard of comparison. However, many investors also wish to know the prospective rate of return (interest). This is the most common measure of profitability used to compare investment alternatives. So both DNW (dollars) and prospective rate of return (percent) will be used in this discussion.

Computing discounted net worth requires estimation of future timber yields, prices of several alternative products, cost of cultural operations, and other costs. The risk of physical losses and of changes in purchasing power of money, and the life of the investment also should be considered. Wide divergence in estimating and weighting each factor can be expected among appraisers. In this discussion, each factor has been estimated empirically. Assumptions are stated so that others whose opinions may differ can substitute their own estimates.

Appraisals were made of individual stands one acre in area as separate units. Evaluation of an entire regulated forest capable of producing sustained annual incomes would result in a higher discounted net worth and higher rate of return than the values shown.

Yield, Cost, and Returns

Timber yield predictions are based on the model stand, site index 60, shown in Table 3 (page 25). Yields

8. Equivalent to discounted net revenue, present worth, and expectation value.

for land of site index 50 and 70 were assumed to be 0.5 and 1.5 times those of site index 60. This generally conforms to the relationship of timber yield to site as shown by Farrell (1964).

Yield and Value of Products

Predicted timber yields in terms of number of trees, diameter, and volume were transposed into product equivalents (Table 5). Diameters were derived from the tree of average basal area. Estimates for stands 30 to 40 years of age were based on actual yields from experimental areas (Brinkman and Rogers, 1965). Stumpage prices for 1967 were applied to products from these young stands. Higher values were assumed for products from older stands. The total value of yields over a rotation is the sum of harvest stumpage value and preceding thinning values. For example, a stand cut at age 40 would have a total yield value of $285 per acre: $225 from the harvest cut plus $60 from the thinning at age 30.

Table 5 provides an indication of the kinds of products and the gross values of periodic yields. Because the combination of sizes, number and value of products cut in a specific operation cannot be predicted, however, only the gross revenues shown were used in the computation of stumpage revenues.

Predicted Stumpage Revenue

For convenience in computing, the yields shown in Table 3 and the gross revenues in Table 5 were converted into average stumpage value per cubic foot of yield by stand age:

Stand age (years)	Thinning	Final Harvest
30	$0.06	$0.06
40	.10	.11
50	.11	.12
60	.14	.15
70	.15	.16
80	–	.17

Losses from all sources of risk were assumed to be 10 percent of gross revenue. The estimated costs per acre for marking trees and supervising timber sales were $3.50 for thinnings and $5 for final harvest of the stand. Based on the preceding values per cubic foot for stumpage and the periodic yields in Table 3, net revenues from stumpage sales at specified ages on site index 60 were estimated (Table 6).

A stand grown to age 30 and harvested would yield a net revenue of $113.80 per acre. If grown to age 60, net returns would be the sum of returns from thinnings at ages 30, 40, and 50 plus the harvest cut for a total of $569.05 per acre.

Regeneration and Other Costs

The major silvicultural investment required is for stand regeneration after each timber crop has been har-

TABLE 5--ESTIMATED PRODUCT YIELDS AND STUMPAGE VALUE PER ACRE, SITE INDEX 60

Stand age (years)	Post and poles: Number	Post and poles: Size [1]		Post and poles: Unit value	Sawlogs: Volume	Sawlogs: Unit value	Total stumpage value	
		Inches	Feet	Dollars	M. ft.	Dollars	Dollars	
				TREES CUT IN THINNINGS				
30	500	3	7	0.06			30.00	
	120	4	18	.25			30.00	60.00
40	136	3.5	8	.07			9.52	
	77	5	20	.50			38.50	48.02
50	22	5	30	1.50	1.1	20		55.00
60	18	7	45	3.00	1.2	25		84.00
70	5	8	40	3.50	2.3	26		77.30
				TREES CUT IN FINAL HARVEST				
30	800	3	8	0.06			48.00	
	230	4	18	.25			57.50	105.50
40	50	5	20	.50			25.00	
	200	6	22	1.00			200.00	225.00
50	100	5	30	1.50	7.0	25		325.00
60					17.0	30		510.00
70					19.0	30		570.00
80					20.0	30		600.00

[1]Diameter at small end in inches and length in feet.

vested. It is assumed (1) that site preparation and stand regeneration are required at the beginning of each rotation, and (2) that control of undesirable hardwoods at the same time will suffice for the life of the stand. Four alternative regeneration methods commonly employed in Missouri were considered:

- *Natural regeneration.* Prescribe-burn to reduce litter and slash. Kill undesirable hardwoods with a chemical silvicide applied either with a mistblower or tree injector or in axe frills.
- *Natural regeneration.* Scarify ground surface by bulldozing. Kill hardwoods; methods stated above.
- *Hand Planting.* Prescribe-burn, kill hardwoods, and plant shortleaf pine seedlings. Machine planting was not considered because of the difficulty of planting previously forested land.
- *Direct seeding.* Prescribe-burn, kill hardwoods, and seed, using a cyclone or similar type of hand-operated seeder. Aerial seeding also is available at lower cost per acre for large areas.

Costs for the several operations described above, incurred on typical sites in Missouri during the years 1961-65, were obtained from several sources.[9] Estimates of average costs for the four methods of stand regeneration are:

9. Including unpublished data provided by the Clark and Mark Twain National Forests and the Missouri Department of Conservation.

Treatment	Cost per acre
A. Natural regeneration	
Prescribed burning	$ 3.00
Killing hardwoods	6.00
Total	9.00
B. Natural regeneration	
Scarifying, bulldozer	10.00
Killing hardwoods	6.00
Total	16.00
C. Hand planting	
Prescribed burning	3.00
Killing hardwoods	6.00
Planting, including cost of seedlings	28.00
Total	37.00
D. Direct seeding	
Prescribed burning	3.00
Killing hardwoods	6.00
Seeding, including cost of treated seed	8.00
Total	$17.00

TABLE 6--ESTIMATED NET REVENUE FROM STUMPAGE SALES, SITE INDEX 60

Rotation age	Thinning age	Net revenue per acre: Thinning	Final harvest	Total
Years		Dollars		
30			113.80	113.80
40	30	47.80		
	40		222.70	270.50
50	30	47.80		
	40	41.50		
	50		297.40	386.70
60	30	47.80		
	40	41.50		
	50	46.00		
	60		433.75	569.05
70	30	47.80		
	40	41.50		
	50	46.00		
	60	72.10		
	70		470.20	677.60
80	30	47.80		
	40	41.50		
	50	46.00		
	60	72.10		
	70	64.00		
	80		530.50	801.90

Because the cost of method B is only $1.00 less than method D, only methods A, C, and D were used in computing DNW and rate of return.

Real property taxes on forest land in the Ozark region in 1963 averaged 21.0 cents per acre (Smith and Mischon, 1965). During the previous nine years, taxes generally had increased 1.08 cents per acre annually. It is assumed that taxes on forest land currently are 25 cents per acre and that they will increase 1.0 cent each year, forever—a realistic assumption for the purpose of appraisal.

Income taxes were not estimated because of the difficulty of assigning a percentage tax bracket to landowners with wide variation in income; many have greater income from sources other than timber. Income from timber enjoys a preferential tax treatment if it is received under certain conditions. Timber depletion charges, road depreciation, and direct timber sales expense reduce taxable income. Net revenue can be taxed as a long-term capital gain rather than an ordinary income. The tax rate on capital gains is approximately one-half that on ordinary income.

In a study of net returns from thinning Douglas-fir stands in Washington from 1949-1961, the tax on incomes from several thinnings ranged from 7.0 to 17.8 percent of gross stumpage revenue and averaged 15.5 percent (Worthington and Fedkiw, 1964). Ratios of taxes to stumpage revenues from Missouri stands probably would be greater because of smaller outlays for roads and selling expenses, but not appreciably so.

Fire protection is provided by the Missouri Department of Conservation at no direct cost to private landowners; it is considered adequate for growing timber without serious losses. General supervision and other operating costs were not included because their cost per acre is small. If estimated at 20 cents per acre annually, proceeds from $4.00 invested to earn 5 percent interest would pay them perpetually.

These operating costs and product prices are expected to follow general trends in the purchasing power of money. Future costs and prices could have been programmed to meet an assumed rate of inflation, for example. But such a supposition would be arbitrary and with limited foundation. An equally arbitrary decision was made to assume that current costs and prices will prevail. This is equivalent to stating that whatever costs and prices occur, the same spread existing at present will continue.

Rotations Compared

Discounted net worth and prospective rates of return were based on an infinite number of rotations, assuming a continuing succession of cycles of stand production to given ages followed by regeneration by one of three methods. This permits comparison of rotations of varying length over a long period. For the range of rotations compared, 30 to 80 years, the net income received from the third and subsequent cycles has a measurable but minor effect on DNW.

Potential rates of return for site index 60 land vary from 2.8 percent to 8.2 percent for rotations of 30 to 80 years with three levels of regeneration cost (Table 7). With a regeneration cost of $9 per acre, the highest rate of return, 8.2 percent, occurs with a rotation of 40 years and declines to 7.1 percent for a rotation of 80 years. With $17 regeneration costs the rate of return also culminates at 40 years (6.8 percent) and rates for other rotations are correspondingly lower. High regeneration costs of $37 reduce the rate of return.

For a given cost of regeneration, however, the rate of return is not greatly different for the range of rotations shown. Forty-year-old trees average 9.5 inches in diameter and 60-year-old trees average 14.7 inches in diameter. Thus, to take advantage of potentially greater revenues from larger trees, landowners would be justified in planning a rotation of about 60 years. High product prices for

TABLE 7--RATES OF RETURN FOR SELECTED ROTATIONS AND REGENERATION COSTS ON SITE INDEX 60 LAND

(IN PERCENT)

Rotation (years)	Cost of regeneration $9	$17	$37
30	7.3	5.4	2.8
40	8.2	6.8	4.9
50	7.8	6.6	4.9
60	7.6	6.4	4.9
70	7.2	6.1	4.7
80	7.1	5.9	4.6

larger trees would make a longer rotation more attractive.

Discounted net worth (soil expectation value) for three rotations and three levels of regeneration cost computed at interest rates of 3, 5, and 7 percent are shown in Table 8. Dollar values would be earned in excess of the rate of interest used in computation. For example, for a rotation of 60 years and a regeneration cost of $9 per acre, $28 per acre would be earned in excess of 5 percent interest. The prospective purchaser of forest land for growing timber thus could pay $28 per acre for land and earn 5 percent on his investment. If he were satisfied with a 3 percent return he could pay as much as $110 per acre—if the appraisal conditions, including risk, appeared realistic. A return of 7 percent would not be possible if land were to be purchased at current market prices, $25 or more per acre. Negative expectation values indicate that the investment could not return the interest rate used.

It should be remembered that these figures for discounted net worth are based on starting with unstocked land and making an immediate investment to establish a stand. Most forest land already supports at least a partially stocked stand, 30 or more years in age. Returns from such lands will be discussed later.

Cost of Regeneration Significant

The rate of return on investment is largely determined by the cost of establishing shortleaf pine (Table 9). A regeneration cost of $10 at the beginning of each rotation of 40 years would result in a rate of return twice as large as that obtained if $50 were required to establish a new stand. The differences in rate of return for longer rotations are less. This suggests that if a large investment is required to establish a stand a longer rotation is justified. In any case, effective ways to obtain stand regeneration at low cost will substantially increase the potential rate of return.

Effect of Site

Land capable of producing more wood in a given length of time will earn greater returns per dollar invested as might be expected. Site index (SI) 60 land will

TABLE 8--EFFECT OF ROTATION LENGTH AND COST OF ESTABLISHING PINE STANDS ON DISCOUNTED NET WORTH (DNW) PER ACRE, SITE INDEX 60

Regeneration costs per acre (dollars)	Rotation	DNW when rate of discount is--		
		3 percent	5 percent	7 percent
	Years	Dollars	Dollars	Dollars
9	40	94	30	7
	60	110	28	4
	80	95	20	0
17	40	83	21	-1
	60	100	20	-4
	80	87	12	-8
37	40	54	-2	-23
	60	76	-1	-25
	80	65	-8	-28

TABLE 9--EFFECT OF REGENERATION COST PER ACRE ON RATE OF RETURN, SITE INDEX 60 (IN PERCENT)

Cost of regeneration[1/] (dollars)	Rotation (years)		
	40	60	80
10	8.0	7.4	6.9
20	6.4	6.1	5.6
30	5.4	5.3	4.9
40	4.7	4.8	4.4
50	4.2	4.4	4.2

1/ Now and at end of each rotation.

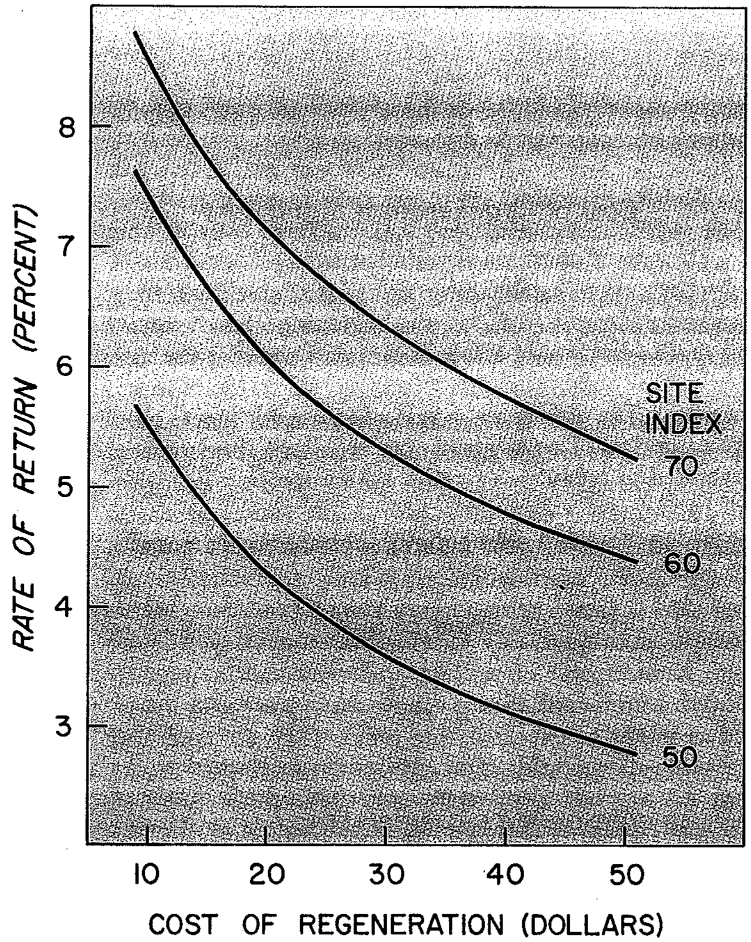

Figure 15. Rate of return associated with cost of regeneration on three sites, rotation 60 years.

earn about 1.7 percent more per year than land classed as SI 50 (Fig. 15). And SI 70 land has a rate of return about 2.7 percent greater than SI 50. Lower regeneration costs result in higher rates of return. Even though it costs more to establish a fully stocked stand of pine on good sites, the rate of return can equal or exceed that for a smaller investment on poorer sites. Obviously, spending large sums on poor-quality land is not justified if the return expected is critically important to the owner.

Discounted net worth for rotations of 60 years, for example, varies substantially with site index and regeneration costs (Table 10). Regeneration costs should not exceed $12 per acre on SI 50 land if a net return of 5 percent is desired. On SI 70 land, about $60 per acre can be invested in stand establishment to earn 5 percent; almost $22 per acre can be justified to earn a 7 percent rate of return.

Returns from Established Stands

In southern Missouri many natural stands of shortleaf pine now 30 to 40 years old resulted from fire protection beginning in the 1930s by the Forest Service and Missouri Department of Conservation. A landowner with such well-stocked stands will escape the initial cost of establishing a stand and revenues will occur sooner. Yields from the first rotation could be expected to return somewhat less revenue because of irregular stocking. However, if the landowner were able to follow a plan of management including scheduled thinnings similar to that described in this paper his potential rate of return could be much greater.

On site index 60 land with a planned rotation of 60 years, discounted net worth per acre of a well-stocked shortleaf pine stand now 30 years of age is much higher than where a new stand has to be established:

Regeneration cost	*Stand age 30*	*Stand age 0*
$ 9	$191	$28
17	189	20
37	184	-1

TABLE 10--EFFECT OF SITE INDEX AND REGENERATION COST PER ACRE ON DISCOUNTED NET WORTH, (DNW), ROTATION 60 YEARS

(IN DOLLARS)

Site index	Cost of regeneration per acre	DNW when rate of discount is: 3 percent	5 percent	7 percent
50	9	40	5	- 6
	17	30	- 4	-14
	37	6	-25	-34
60	9	110	28	4
	17	100	20	- 4
	37	76	- 1	-25
70	9	180	52	13
	17	171	43	5
	37	147	22	-16

The shorter waiting period to the first major harvest, 30 years, is responsible for most of the difference. In fact, the effects of different levels of regeneration cost in the future are largely cancelled by the overriding weight of revenue receivable in the near future. The prospective rate of return from an investment in timber management, beginning with a 30-year-old stand, exceeds 20 percent. Thus, owners of natural stands of pole-size shortleaf pine are in an excellent position to earn an attractive rate of return from timber growing.

Summary

Shortleaf pine is the only pine native to Missouri. Faster growing and easier to manage than most associated hardwood species, pine has excellent potential for commercial production. Small trees can be sold for posts and poles, and pine sawlogs are worth more than most oak logs. In managed pine stands, total volume produced in a rotation will be at least 40 percent more than in oak stands on comparable sites.

In the Missouri Ozarks, pine is found within a gross area of some 6 million acres where pine usually grows in mixture with oaks and other hardwoods. Pine has been widely planted on both old-field and forest sites within and outside the species' original range.

Although pine occurs naturally where the black oak site index may range from 30 to 80, pine management may not be profitable where site index is less than 45 and the oaks will overtop pine where site index exceeds 65.

New pine stands may be established naturally where a good seed source is present or they may be direct-seeded or planted in other areas. In most cases, excess hardwoods must be controlled. Prescribed burning may be necessary to prepare the seedbed before natural seedfall or before direct seeding to convert poor oak stands to pine.

Trees will be 35 to 40 feet tall by age 25 on average sites. Annual height growth averages a foot a year between ages 25 and 40, 0.8 foot from ages 41 to 60, and 0.5 foot in older stands.

Good diameter growth rates require that live crown length be at least one-third of total height. Diameters of post-size and larger trees increase about two inches with every 10-foot increase in total height. By age 70, dominant and codominant trees will average 17 to 19 inches d.b.h.

Fire and insect losses are low in the pine type. Root rot (*Fomes annosus*) is a potential but controllable threat to pine plantations on old-field sites but is not a problem on forest sites.

Pine and oak-pine types should be managed as even-aged stands. Thinnings in pine stands may be made at 8- to 10-year intervals beginning about age 25. To favor potential crop trees, all unwanted hardwoods should be killed or sold. Economic rotation age usually is 60 to 70 years, depending on current growth rates and anticipated markets. Site quality and the cost of regenerating pine stands are the most important factors affecting interest earned on the forest investment.

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